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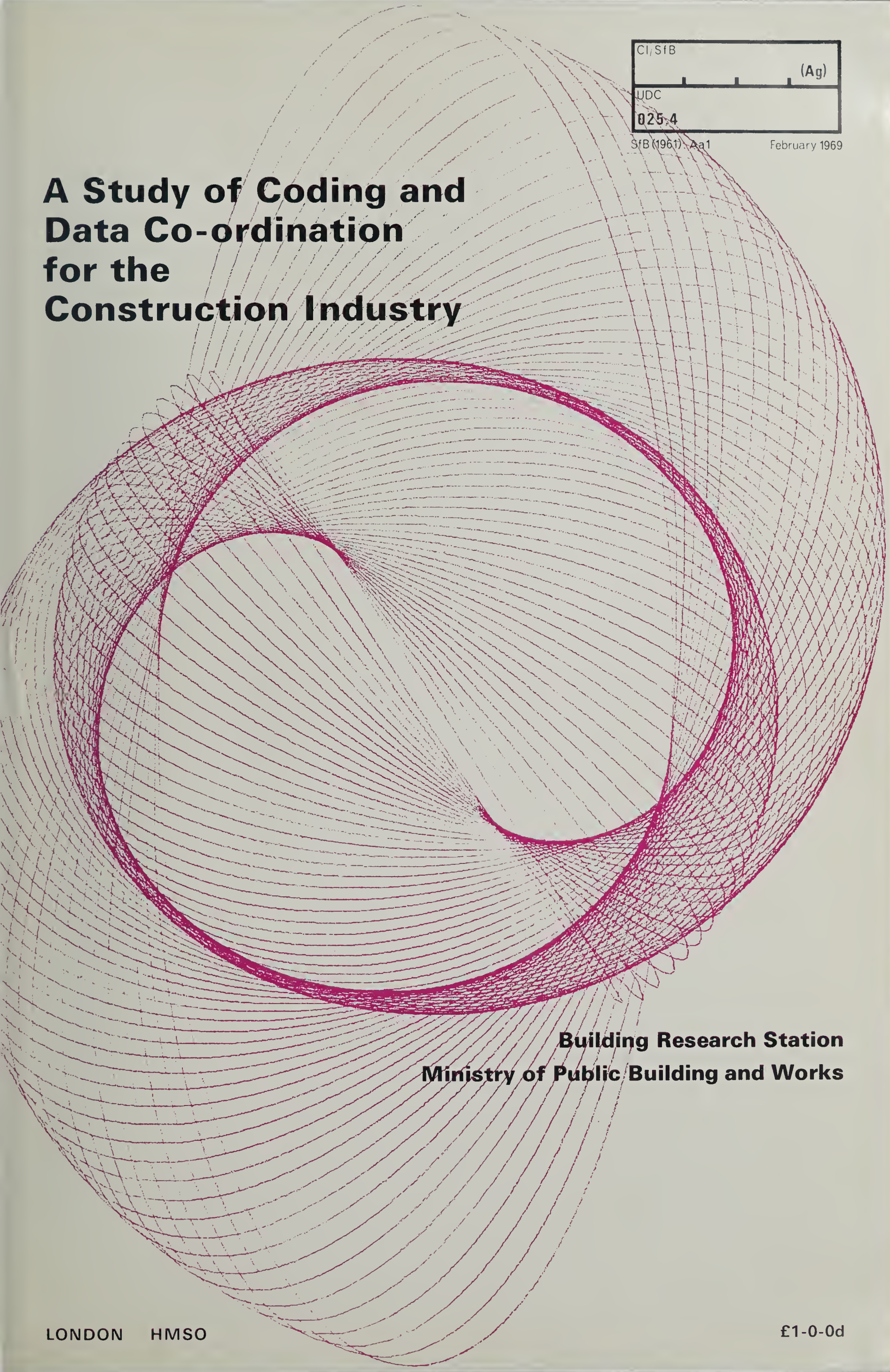
A Study of Coding and Data Co-ordination for the Construction Industry



Building Research Station
Ministry of Public Building and Works

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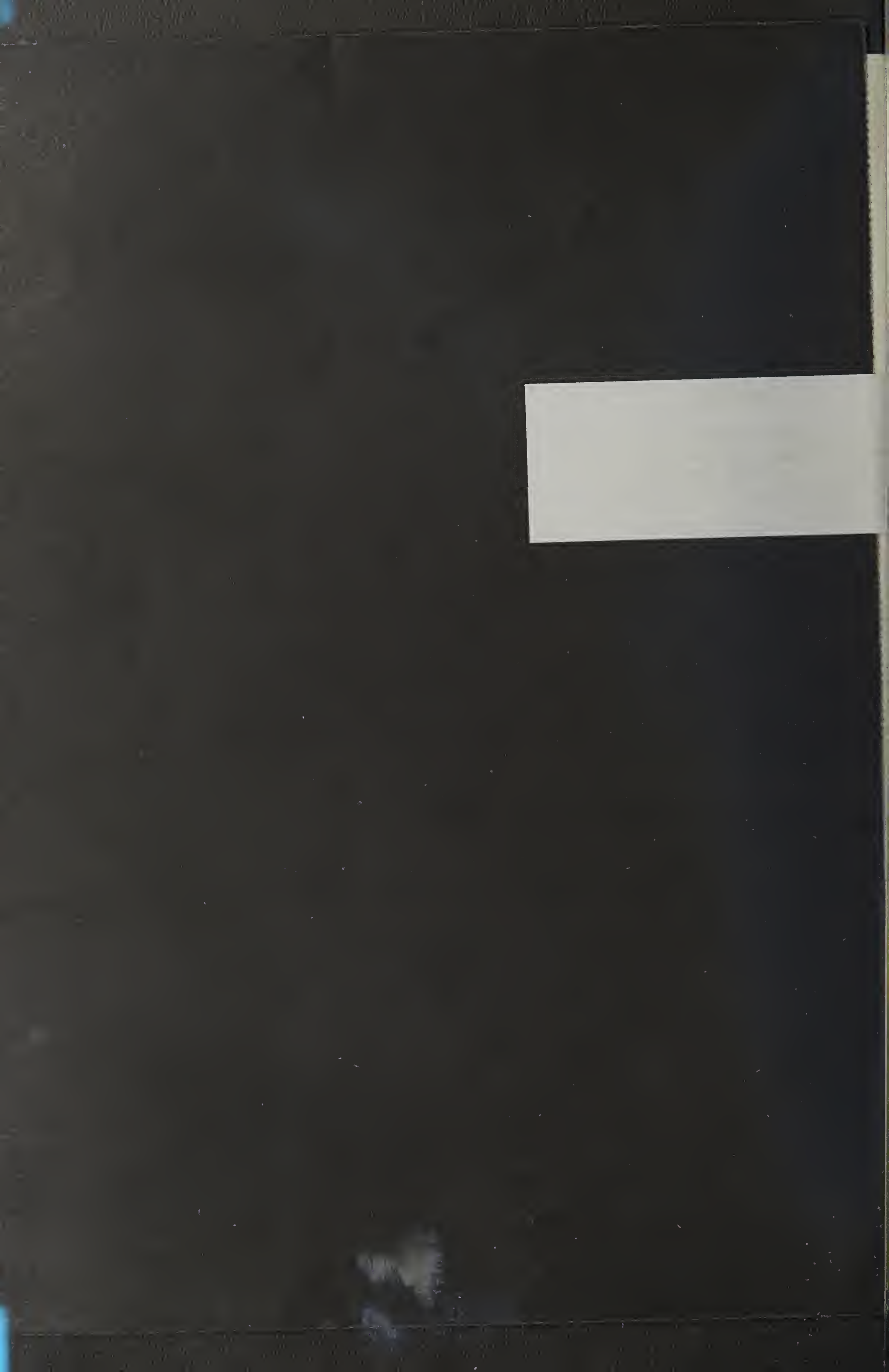

Building Research Station
Ministry of Public Building and Works

A Study of Coding and Data Co-ordination for the Construction Industry

Report prepared for the Sub-Committee on Coding and Data Co-ordination of the Committee on the Application of Computers in the Construction Industry

D. Bishop ARICS MICE
K. Alsop BSc AInst P

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Foreword

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This report is only a beginning. It describes an onslaught on the problem of communications in the building industry, undertaken specifically to provide criteria against which information systems designed to serve industry in whole or in part could be judged. These criteria and the consequent recommendations for practical action are summarised, for easy reference, in chapters 7 and 10.

But this *is* only a beginning. What is needed now is effective action within the industry. The Minister of Public Building and Works has announced that his National Consultative Council for the Building Industry is to take this work under its wing, so as to provide impetus and co-ordination to the many sectional initiatives that are likely to follow.

The Station itself will be continuing its work in this important field and thus will be able to make further contributions from time to time.

This report could, if widely applied, result in a real increase in the efficiency of the operations of the industry. It has been written essentially for those who will have to implement it.

John Weston
Director, Building Research Station

December 1968

Building Research Station
Garston
WATFORD WD2 7JR

Contents

		Page
Chapter 1	**Terms of reference and the background to the study; criteria and recommendations**	1
	The findings	3
	Criteria	3
	Recommendations	4
Chapter 2	**The building process and systems of information**	6
	The building process	6
	A model of the building process	6
	Information systems	8
	An information system derived from the model of the building process	9
	Consequences of the assumptions made	9
Chapter 3	**The rôle of data co-ordination in the building process**	14
	Architectural design	15
	Structural engineering	23
	Mechanical and electrical engineering services	27
	Construction	30
	Design realisation	40
	Materials suppliers and manufacturers	44
Chapter 4	**The purposes of an information system for the building process**	50
	What an information system must do	50
Chapter 5	**Practical and technical considerations**	56
	Practical considerations	56
	Commercial considerations	57
	Human factors	58
	Vehicles of communication	59
	Computer considerations	60
Chapter 6	**Coding aspects**	68
	General benefits of codes	68
	Documents	69
	General criteria for designing codes for documents	70
	Some features of codes	70
	An illustration of a code for the construction industry	74
Chapter 7	**Criteria**	75
	Practical considerations	76

Commercial considerations 76
Human factors 76
Criteria for codes for documents 76

Chapter 8 **A framework** 78
To classify information 78
To identify and describe resources 78
To describe projects 79
To foster the development of procedures 79
To support information flow 79
A preferred vocabulary 80
Classification 80
Classification facets 86
Conventions 86
A central commodity file 90
Procedures 91
Assigned codes 92

Chapter 9 **Implementation** 94
Development of the framework 94
The organisation necessary 96

Chapter 10 **Recommendations** 98
The framework 98
Implementation 98

References 99

Acknowledgements 10

Appendix A **Ministry of Public Building and Works Sub-Committee on Coding and Data Co-ordination** 10

Appendix B **The Study Team** 10

Appendix C **Verbs for describing procedures** 10

Appendix D **Sectional reports** 10

Appendix E **Occupational classification for operatives** 10
prepared by J. I'a Nelson BA

Appendix F **Classification facets** 11

Appendix G **Implementation: priorities and costs** 11

Appendix H **An illustration of a code for the construction industry** 12
prepared by D. Whiteside BSc

Glossary 14

Chapter 1

Terms of reference and the background to the study; criteria and recommendations

1-1 For long enough many people in the industry have felt that something should be done to improve communications and to facilitate access to data on e.g. materials, products and commodities, regulations, standards, costs etc. Additionally many have been uneasy about communications in the industry, particularly information made available to contractors, and the way in which data produced by one member of the building team may be independently produced again by others, either because they are unaware that the data already exists, or because they know it exists but cannot get access to it sufficiently readily, or because the form is not right for their requirements. Finally it has been suspected that some of the less efficient practices stem from the uncertainty created by the inadequacy of information flow.

1-2 In May 1966, the Minister of Public Building and Works set up the Committee on the Application of Computers in the Construction Industry, to foster the effective use of computers in the industry. The Committee quickly decided that there was a prima facie case that, if the industry were to get the best out of computers, there must be a system of data co-ordination and coding applicable to the whole industry, if the development of such a system proved feasible. This subject was remitted to the Sub-Committee on Coding and Data Co-ordination (Appendix A) under the chairmanship of Mr. Alex Gordon, OBE, FRIBA, and the Building Research Station undertook to provide a team (Appendix B) to carry out, under the guidance of this Sub-Committee, a study with the following terms of reference:

'To study the present characteristics and probable development of the information used in the design and execution of construction work; to determine the criteria for a coding system which would enable computer-processed information to be used more effectively, both within the individual firms and offices and in communication between them, thereby leading to greater efficiency and economy; and to make recommendations.'

1-3 The Station's interest in communications in the building process had been largely confined to three areas: tender documentation, especially the development of operational Bills of Quantities[1, 2]; the recording of expenditure of money and labour on building sites [3, 4, 5, 6, 7]; and the communication of the results of its own research[8]. This new study entailed an entry into a very broad and largely unfamiliar area of research with the commitment to produce a report within a period of 21 months, a period that included time spent in appraising the situation and in gathering together a team. In all its work the team has been materially assisted by the Chairman and members of the Sub-Committee, with whom they have maintained a frank exchange of views.

1-4 Because communications take place within the existing structure of the industry, defined by the organisations concerned and by the rôles fulfilled by individuals, it might seem that a study of data co-ordination must be related to this structure. This would have severely constrained the study. The building industry in the United Kingdom is diverse, with considerable separate specialisation in design and in construction. Much design, including detailed design, is undertaken by professional firms working in isolation from the construction side of the industry. In practice this is now being modified in many different ways, ranging from the development of building systems by consortia of clients, frequently for the construction of a limited

range of building types, to package deals negotiated between clients and contractors, the latter providing a wide range of services including finance, design and construction. It would have been extremely difficult to mount a study to encompass every aspect of this shifting scene; the time available made it impossible.

1-5 What the study concentrated on, therefore, was the various functions that are performed during the building process (irrespective of who they are performed by) and, in particular, the information needed, the information that results, and the functions from which and to which this information passes.

1-6 The study shows that there are certain basic items of information that are of concern to all participants in the building process and that all participants need access to data from past projects, as well as to the general information such as regulations, codes, standards, design criteria, etc.

1-7 To be more specific, all participants need access to the client's brief as it develops, and to statements of any constraints within which they must work.

1-8 All participants also need to know the form the building will take, information that starts in a tentative and imprecise form that is progressively made more and more precise. All participants need to know—and to contribute to—the latest 'state of play'.

1-9 All participants are concerned with the resources employed in building—material, human, and equipment—and with ways of identifying and classifying them.

1-10 Finally, all participants need to draw on experience from past jobs and on information of general character—performance requirements, detailed regulations etc.—that apply to the project in hand.

1-11 The objective of data co-ordination is of course, improved communications, but data co-ordination alone is not enough. Improved communications will demand changes in some of the current practices of the industry.

1-12 Some of these changes can be made easily, others will require the consent of participants in order to modify established ways of working, perhaps falling within the domain of the industry's consultative machinery. They include:

Appointment of a combined team for feasibility studies so that specialists can contribute their different skills to determine the options open to clients and their cost and profitability

Preparation of comprehensive briefs as a separate task from the feasibility study

Appointment of combined design team to prepare scheme designs so that specialists can make constructive contributions before irreversible decisions have been taken, and thus make optimised designs more likely

The inclusion in project management of programmes for information essential to the orderly progress of projects and the management of information flow so that all involved with design and construction are informed quickly when amendments or additions are made

Appointment of main and sub-contractors in such a way that they have the opportunity to integrate their programmes for work on site.

1-13 Other improvements to communications would stem from the preparation and use of standards to avoid regenerating almost identical information for each project. Such standards would include national standard specifications for building, civil engineering, mechanical engineering and electrical work, and these could be supported by standard details.

The Findings

1-14 The purpose of the study, given in the terms of reference, was to produce criteria and recommendations. It may help to set the rest of the report in perspective if these are set out at this point.

Criteria

1-15 The criteria that are applicable to schemes for data co-ordination and coding are as follows. The first set arise directly from the needs of the building process. Any scheme claiming to be comprehensive must:

1 *Classify information* in sufficient categories for users' needs, and in particular to allow data to be retrieved in order to:

search through data about building types, functional systems, technical solutions, building elements, constructional methods, resources, commodities, materials, occupational groups, equipment;

select functional system, technical solution, arrangement, construction method and resources with regard to performance, specification, availability and cost;

check compliance with constraints and with regulations.

support feedback within and between projects.

2 *Identify and describe resources*

to identify uniquely commodities (materials, products and components embodied in construction), contractors' materials, consumable stores, equipment (plant and tools) and occupational groups, in a way that will be convenient for the industry's transactions;

to provide the means by which unique identifications can be assigned to commodities etc;

to produce comprehensive central commodity, contractors' materials, consumable stores and equipment files.

3 *Describe projects*

to describe form* by co-ordinates or other methods;

to describe the technical solutions by describing work-pieces, identifying or specifying commodities comprising work-pieces, indicating the circumstances in which the work-piece will be completed, locating work-pieces within projects, and stating restraints to be observed;

to describe operational methods by identifying the construction method, defining activities, specifying the resources to be employed, depicting the sequencing and timing of the resources, resource scheduling, and progress reports and costings.

4 *Foster the development of procedures**

to provide categories necessary for data retrieval in ways to suit the needs of specialist procedures;

to enable documents (drawings, schedules, specifications, bills of quantities, programmes, project proposals, resource schedules), to be arranged in ways convenient to procedures;

to provide the means of co-ordinating conventions evolved for specialist procedures or groups of procedures, a task that includes the development, revision and extension of a preferred vocabulary;

to provide the means to prepare suites of related procedures.

5 *Support information flow*

to identify, for various users, the ways in which information should be structured in order to meet their requirements and to avoid interpretation from another form;

* See glossary

to establish a structuring for the documents used in the industry;

to identify the categories of information relevant to each document;

to provide systems cross-referencing between documents;

to establish a framework for accepting, identifying and categorizing standard details, and specification preliminary and preamble clauses;

to provide the means of co-ordinating such standardisation;

to provide the means of making methods that allow the multiple use of data known and adopted.

1-16 The above criteria stem directly from the needs of the building process. In addition, the following criteria rest on other practical and commercial considerations:

A system must be capable of implementation in stages

A system must be hospitable to separate, but related, sub-systems

A system must include the means to co-ordinate its development

A system must involve the industry in its development because implementation will affect the whole industry

Vehicles used for conveying information must be adequate in content, clear, reliable and economical

A system should not cloud the responsibilities of participants

A system must preserve commercial and professional security.

1-17 The characteristics of a system should be acceptable to users and adapted to suit their experience and interests.

1-18 The following criteria apply to codes used to gain access to documents:

For input documents
Accurate production and checking of codes should be easy. This implies that encoding procedures should be appropriate to the skills of the persons involved and that time for referring to code keys should be minimised

They should be short for economy of input document production (writing, punching etc.) and computer input time

Symbols appropriate to computer input devices should be used

Computer time for input codes to be translated into on-file document codes should not be excessive.

For on-file documents
Codes should be short for economy of storage and internal computer transfer time

They should be suitable for the types of file processing required such as retrieval, sorting, producing output in order to minimise processing times.

For output documents
Codes should be easy to interpret by the user and therefore appropriate to his skills

They should be appropriate to the computer output facilities.

Recommendations

1-19 The work of the study team has resulted in recommendations for a framework that would serve to co-ordinate information systems. It would consist of:

1 *A preferred vocabulary* that would consist of the descriptors used in other parts of the framework.

2 *Classification categories* to allow information to be filed, retrieved and sorted in ways useful to the industry. The following categories are recommended:

Building type Functional system Building element Technical solution Commodity Construction method Work section Work element Operative occupation Plant and equipment.

3 *Conventions* for feedback and performance data, for procedures and for production information.

4 *A central commodity file* in which information about materials, products and components would be systematically made available, at first from standardised technical literature but later computer based.

5 *Procedures* developed preferably in related suites, for formalising many of the functions performed in the building process as a prelude to the wider use of computers.

6 *Codes* to make the transmission of information more reliable and more economical.

1-20 This framework would serve the information needs outlined in paras 1-7–1-10. Thus, the client's brief and the form of the building will require conventions for the presentation of production information and a vocabulary from which words used in descriptions are drawn. If form is to be computerised, procedures will be needed, drawing on conventions and vocabulary and making use of codes. A description of resources will use most of the components of the framework: vocabulary, conventions (particularly for performance), classification categories for filing and retrieval. Feedback and data retrieval will draw on all parts of the framework. The procedures have an importance of their own in that they handle, operate and transmit the data so that the data lives and achieves the functions of the industry.

1-21 Recommendations for implementation will require both central and sectional activity:

1 Sectional activity would be concerned with the development of procedures, with some aspects of coding, and with contributions to the commodity file.

2 A central organisation is recommended to advise on sectional action and to co-ordinate it, to collate information on implementation and to supervise the vocabulary, the classification facets, the conventions and the commodity file, and generally to promote the use of data co-ordination and the identification of research and development needs.

General

1-22 Three reservations must be added. The study has been focussed on building, neither the time nor the staff available making it possible to cover civil engineering. The team believes, however, that the broad conclusions and much of the detail are applicable to civil engineering. The study has not dealt with maintenance, except in so far as maintenance costs and experience are an essential part of performance feedback. In the field of management, the study has concentrated on the management within contractors' organisations, though it is believed that the same principles will be applicable elsewhere.

1-23 There is from the study considerable evidence of an awareness throughout the industry of the need for data co-ordination, and it is likely that measures to implement the findings of the study would find strong support if the implementation were carried out realistically. There is, however, no suggestion that everything to which this report points could, or should, be implemented at one and the same time. Within the framework proposed there is ample room for the encouragement of initiative by individuals and organisations in various sectors, provided these are consciously directed in a manner that will meet the widest needs, and do not strike out on an entirely individualistic line.

Chapter 2

The building process and systems of information

2-1 In this chapter two major assumptions made during the course of the study are explained; the first concerns the model of the building process adopted for this study, the second an information system to reflect it. Both are fundamental to the outcome, but are difficult to justify by argument since it is impossible to demonstrate that no better models exist. Because of this, the paths by which these assumptions were reached will be traced, and the discarded alternatives briefly indicated.

The building process

2-2 At the outset it was believed that the study should take the form of a number of case studies of individual projects, in order to determine the character of information passing between participants, an approach that probably stemmed from the operational bias of the Station's previous work.

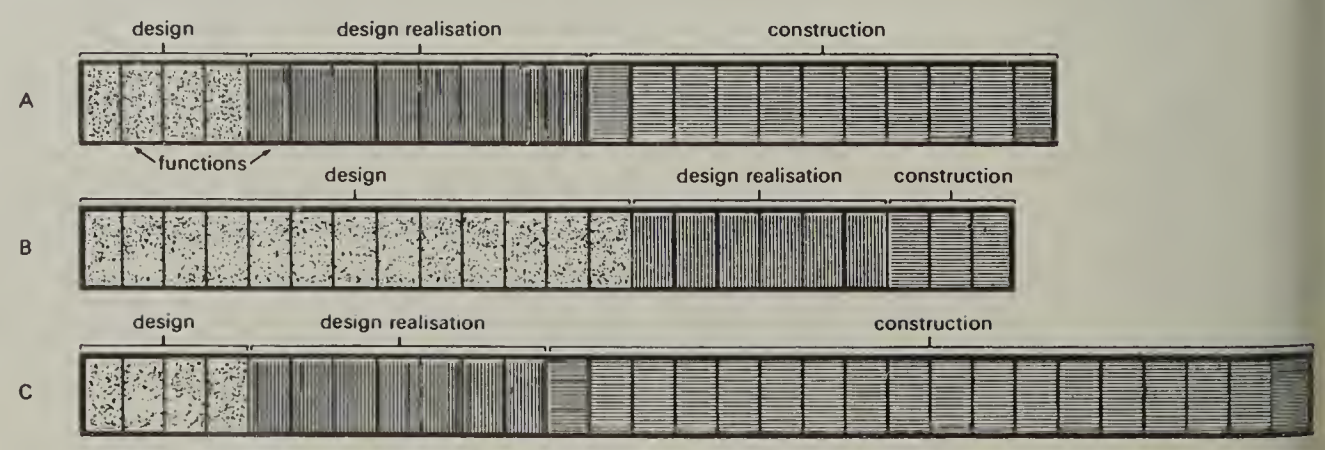
2-3 Practical considerations prevented this course being followed; the scale of the industry, and the numerous arrangements of designers, specialists, main contractors and sub-contractors would have demanded a multiplicity of case studies of projects. With the time and resources available, it would not have been possible to study more than a small number of the arrangements that actually exist and any conclusions drawn from the study would have been of limited applicability. Extensive case studies, even if practicable, would only have shown the variety that exists in the industry—a fact already well known.

2-4 Attention was therefore focussed on the functions* discharged, each function being the achievement of an identifiable goal. That is, the study was no longer concerned with the roles fulfilled by particular groups of people: with who does what. Neither was it found necessary to assume any particular sequence of functions. One incidental consequence of making this assumption has been to give this report a slightly abstract tone, since little reference is made to the rôles normally recognised in the industry—architect, quantity surveyor, contractor, etc.

A model of the building process

2-5 The model of the building process adopted for this study is simple. Every building project is assumed to be discharged by the execution of functions, each marking the achievement of an identifiable goal (Fig I.a) a different project will entail some

Figure—1 Individual projects



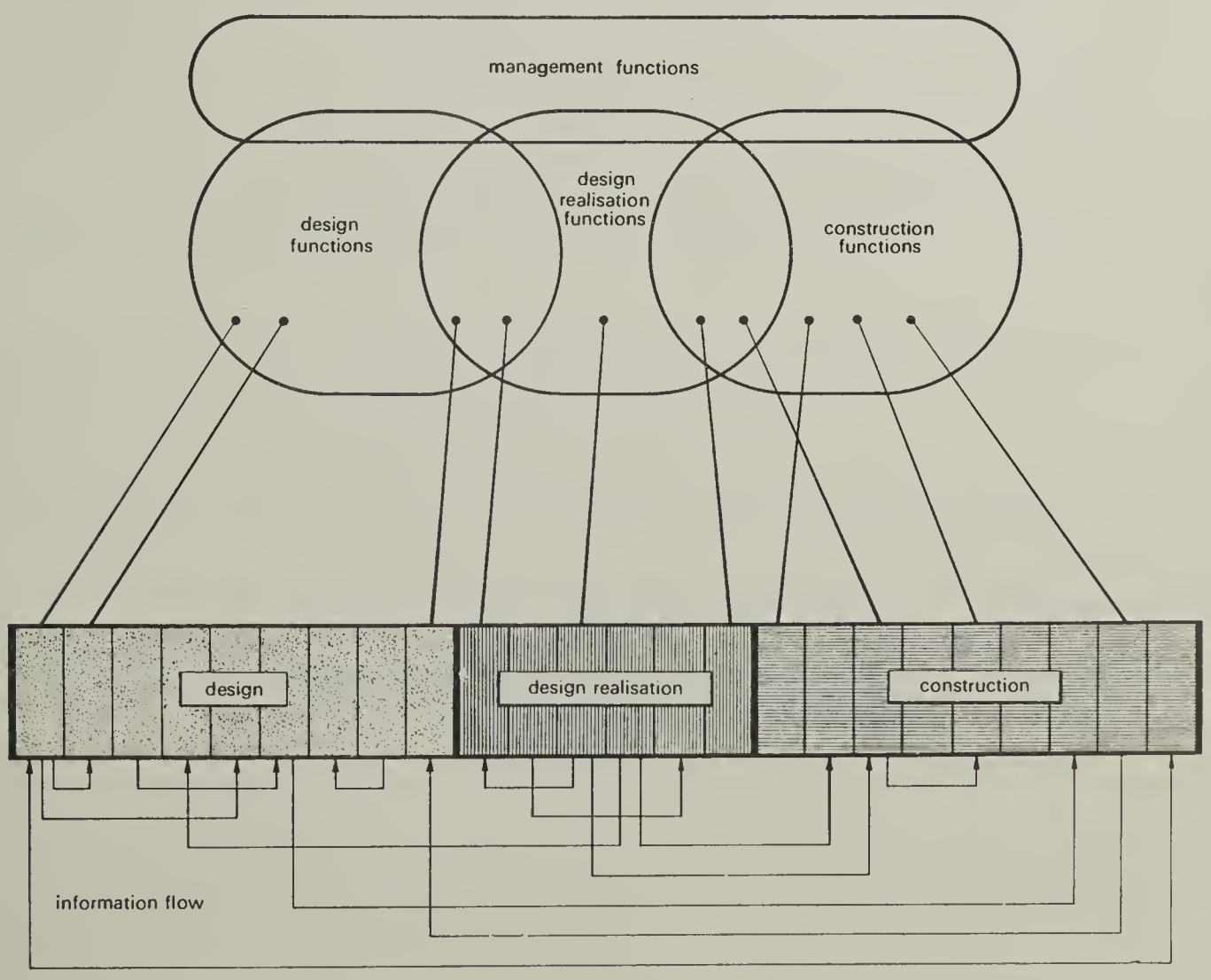
* See Glossary

functions common to the first project and some new ones (Fig I.b); and so on for other projects (Fig I.c).

2-6 For convenience these functions are considered in four groups, design, design realisation, construction and management. By design is meant those functions that use scientific principles, technical information and imagination, to define a project capable of meeting specified requirements with economy and efficiency (a modification of a definition used in the Fielden Report). By construction is meant the planning of work, including financial budgeting and control, and the allocation, acquisition and deployment of resources on site to achieve the completion of a project. All that lies between design and construction has been designated design realisation. It normally commences when the design has resulted in the choice of principal structural techniques and materials, and is completed at the commencement of planning of constructional work on site and resource allocation. It is this design realisation group of functions that is likely to benefit most immediately from any system of data co-ordination, although, in the long run, the benefits derived from data co-ordination by the design group of functions could be more decisive and substantial. In addition to these three groups of functions, each concerned with the completion of a project, there is a fourth group of general management functions, embracing the management of organisations of whatever kind. All individuals and organisations face similar problems; obtaining work, acquiring and deploying resources*, and planning and controlling functions, and there is no reason to suppose that the information required to discharge these functions is much affected by the type of resources that are being deployed.

2-7 Hence, for all possible projects, the four groups, design, design realisation, construction and management will be composed of sets of functions which do not depend upon the structure of the industry or on the order in which they are discharged (Fig. 2).

Figure—2 Projects in general



* See Glossary

2-8 Information passes from function to function, some between only two functions and some between several. Because any project is made up of the appropriate selection of functions, the information requirements of a project are determined by the functions entailed and their inter-relationship.

2-9 Each function is assumed to be completed by a number of procedures, having a similar relationship to a function as functions have to projects. Procedures are formalized ways of executing tasks having identifiable end-points, with no distinction between occasions when a task is, or could be, completed during one stage and when the same task is, or could be, completed only after several stages, perhaps involving iterations or revisions as more information becomes available.

2-10 Some procedures will be unique to a function, for example the procedure 'design structural frame type A', is unique to the function 'design structure'; others are common to two or more functions, for example the procedures of 'buying' and of 'resource allocation'; others are more general, for example the procedure 'data retrieval' is encountered in the majority of functions. For any function, many alternative procedures may be available, each requiring different information.

2-11 Procedures may be more or less accurately specified. Procedures which, once selected, involve no judgement are termed determinate procedures; in these, conclusions are reached without recourse to subjective decision; for example, structural calculations for a frame are determined by the assumptions implicit in the mathematical model, by the geometry of the frame and by physical realities (e.g. the properties of the materials, the restraints provided by the joints, etc.). Non-determinate procedures, in contrast, draw on experience and knowledge to assess the non-measurable characteristics. Many procedures are combinations of separable determinate and non-determinate procedures.

Information systems

2-12 The course of the study also saw a change in the team's ideas about information, information flow and data co-ordination. At the outset the intention was to study, by observation, the flow of information between individuals and organisations in order to distinguish the various sources and recipients, the content of the information sought and received, and the relevance and usefulness of various vehicles* in differing circumstances. In the event, detailed case studies were not mounted, for the reasons already explained. By that time, pilot studies had shown that little would have been obtained from case studies; they would have mainly illustrated the degree to which the information actually used is determined by the prior experience (including education and training) of the person or organisation observed. Again neither an original nor a useful discovery!

2-13 For a short time the team tried linguistic methods, in order to derive a language for construction, but this was abandoned when it was realised that it would not lead to criteria and to the development of a framework for future development. These ideas proved fruitful, however, when applied to the functional model of the building process, by then adopted.

2-14 Each procedure can be considered as a number of operations* applied to a set of data. For example, the procedure, 'establish temporary bench marks' involves transferring survey data to setting-out pegs, by the measurement of angles and distances, a task that could be described by an explicit set of instructions (a routine)*; the procedure 'calculate heat losses' involves manipulating information about the form of a project, the thermal properties of the external envelope, and the internal and external environment, by a number of discrete steps, again a routine. The procedure 'make bid' involves applying judgement (informed by experience) to data about estimated costs, the market, and the company's work-load and finances, and again the steps to be followed can be stated explicitly as a routine.

* See Glossary

2-15 It is convenient for routines to be represented as flow diagrams* similar to those used in computer processing. It is sufficient to note that the process, as interpreted on the diagram, proceeds by single steps that are either operations (enclosed in rectangular boxes) or decisions (enclosed in rhomboid boxes), that some of the operations may be described in greater detail in another related routine, and that iterative loops are allowed although parallel processes are avoided as far as possible. Operations (the verbs) are of two kinds, those defining mechanical or arithmetical operations (serving determinate procedures), and those defining subjective operations (serving non-determinate procedures); examples given in Appendix C could form the basis of part of a preferred vocabulary for building. Indeed, if routines are seen as providing the syntax and operations the verbs, the data may be regarded as providing the nouns and adjectives on which the verbs operate, and the relationship to a linguistic approach to the problem of data co-ordination will be seen.

An information system derived from the model of the building process

2-16 Functions are discharged by the execution of procedures in which information is received, processed and put out. Some procedures serve more than one function, some serve only one, so that any function would be made up of the appropriate selection of procedures.

2-17 A procedure may entail only one operation applied to a set of data. More often, however, there are a number of operations which have to be, or can be, carried out in a given sequence. The description of the operations and their sequence is termed a routine. Hence procedures are sets of data as input(s) and output(s) operated on by routines.

2-18 A routine consists of a description of each operation and the sequence of operations, the latter being indicated on a flow diagram. Operations are described by verbs (and adverbs) which are given a formal definition, e.g. a program language when computers are used to process a determinate routine.

2-19 A distinction is made between project data on the one hand and information to be retrieved from general sources on the other. By project data is meant the data that develops with a project and is specific to it, starting with a statement of the client's requirements and concluding with the appraisal of the way in which these requirements have been met. During this process reference must be made to the sources of more general information, not specifically related to the project under consideration. Some of this may be acquired by way of feedback from previous projects, e.g. information recording past performance and costs; the majority will be drawn from catalogues of products etc., from regulations or standards, or from the conspectus of knowledge available to the industry.

2-20 Parts of typical procedures and their associated information schedules* are shown in Fig. 3, 4, 5.

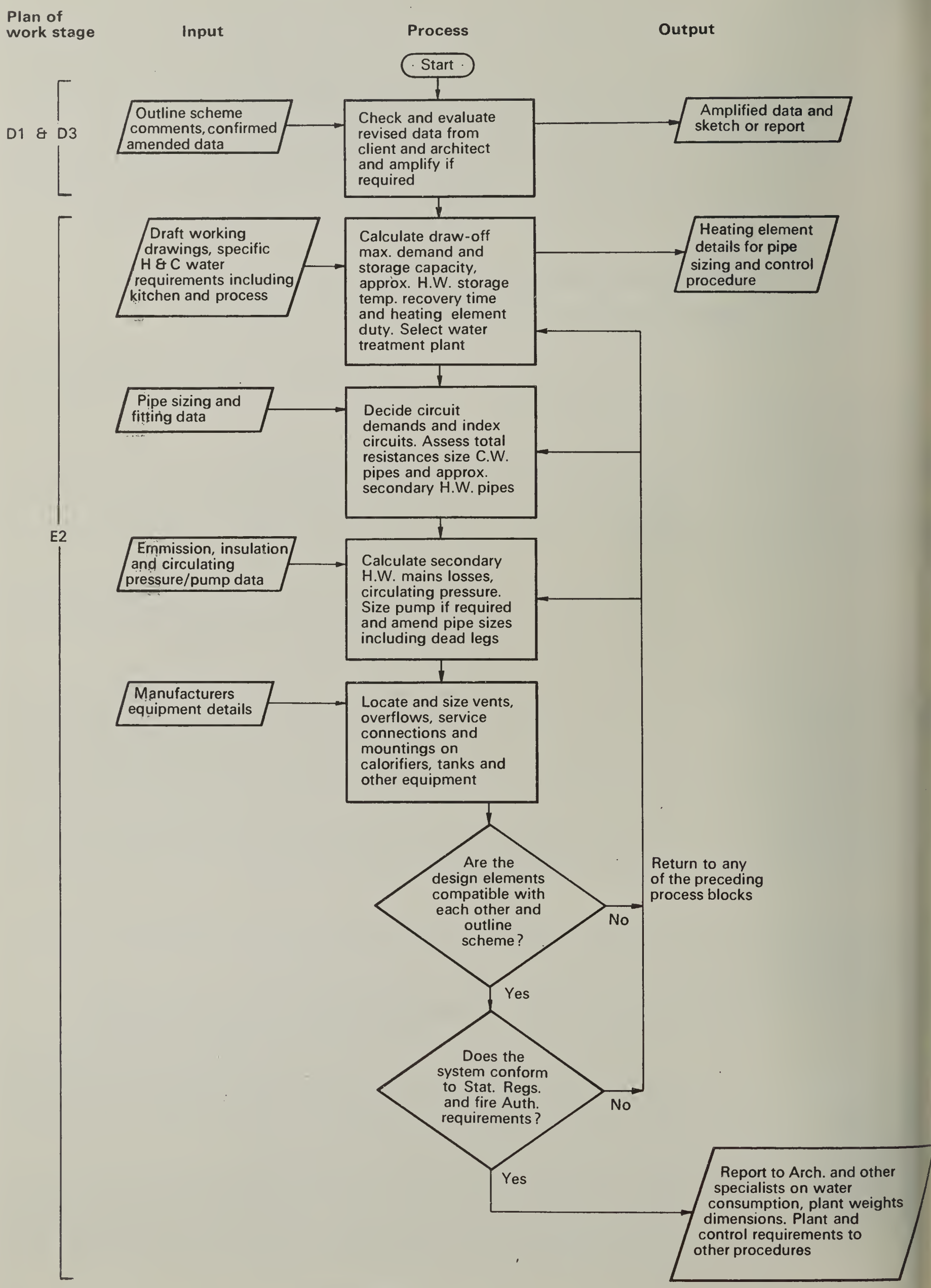
Consequences of the assumptions made

2-21 By concentrating on functions and on the means of fulfilling them, the study has produced criteria and a framework for data co-ordination believed to be independent of the present arrangement of the industry and the rôles fulfilled by organisations and individuals, an important advantage, since both of these are likely to be decisively affected by computer application.

2-22 It is not expected that any of the many procedures (or the information schedules associated with them) developed during the course of the study are necessarily ideal for any actual project, only that the routines and schedules are perfectly practicable and could therefore be used. Field studies have amply demonstrated that this is the case.

* See Glossary

Figure—3 Hot and cold water services design including tanks and calorifiers
(An example of a determinate procedure)


Plan of work stage
Input
Process
Output
Start
D1 & D3
Outline scheme comments, confirmed amended data
Check and evaluate revised data from client and architect and amplify if required
Amplified data and sketch or report
Draft working drawings, specific H & C water requirements including kitchen and process
Calculate draw-off max. demand and storage capacity, approx. H.W. storage temp. recovery time and heating element duty. Select water treatment plant
Heating element details for pipe sizing and control procedure
Pipe sizing and fitting data
Decide circuit demands and index circuits. Assess total resistances size C.W. pipes and approx. secondary H.W. pipes
E2
Emmission, insulation and circulating pressure/pump data
Calculate secondary H.W. mains losses, circulating pressure. Size pump if required and amend pipe sizes including dead legs
Manufacturers equipment details
Locate and size vents, overflows, service connections and mountings on calorifiers, tanks and other equipment
Are the design elements compatible with each other and outline scheme?
No
Return to any of the preceding process blocks
Yes
Does the system conform to Stat. Regs. and fire Auth. requirements?
No
Yes
Report to Arch. and other specialists on water consumption, plant weights dimensions. Plant and control requirements to other procedures

re—4 **Project selection** (An example of a non-determinate procedure)

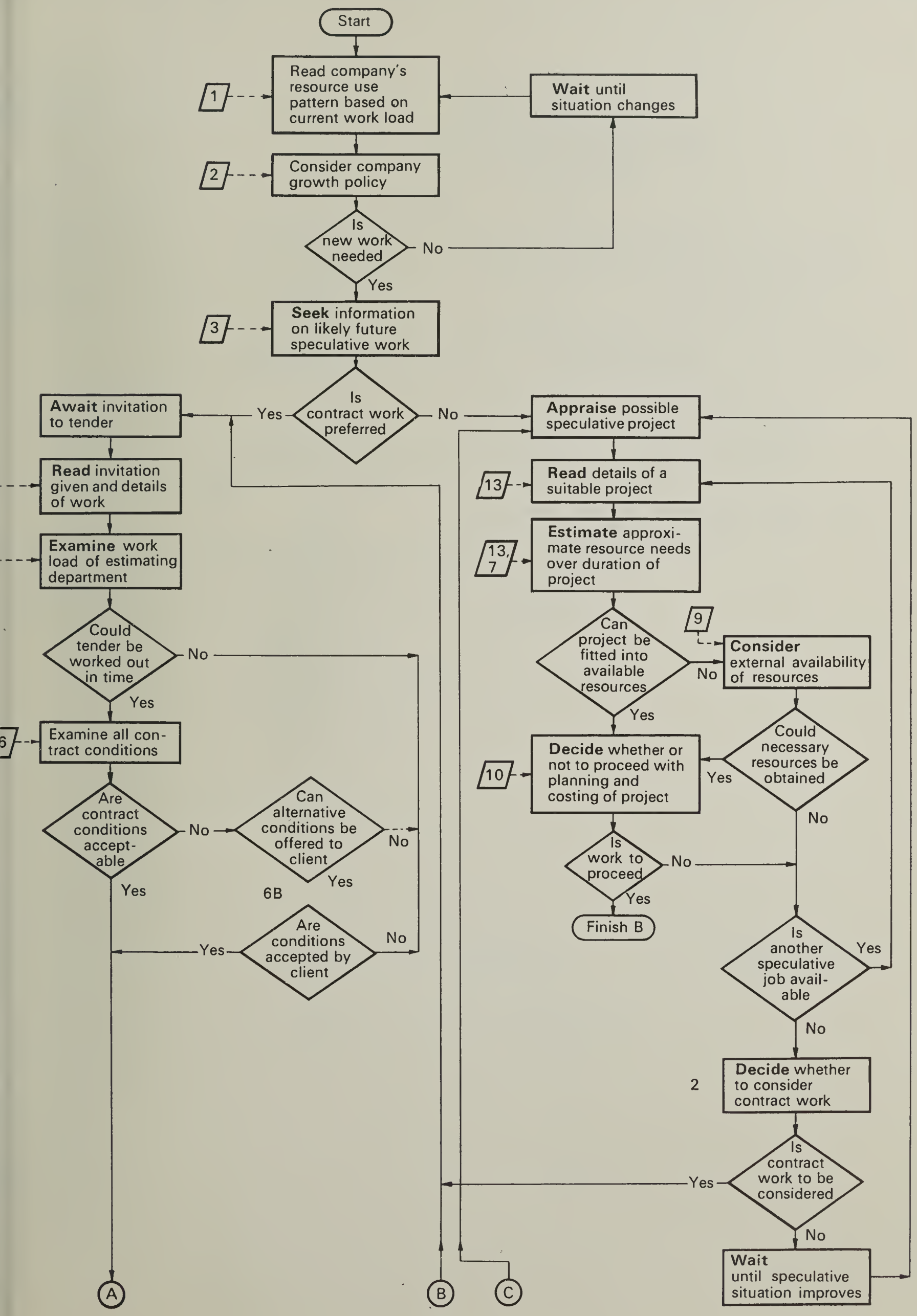
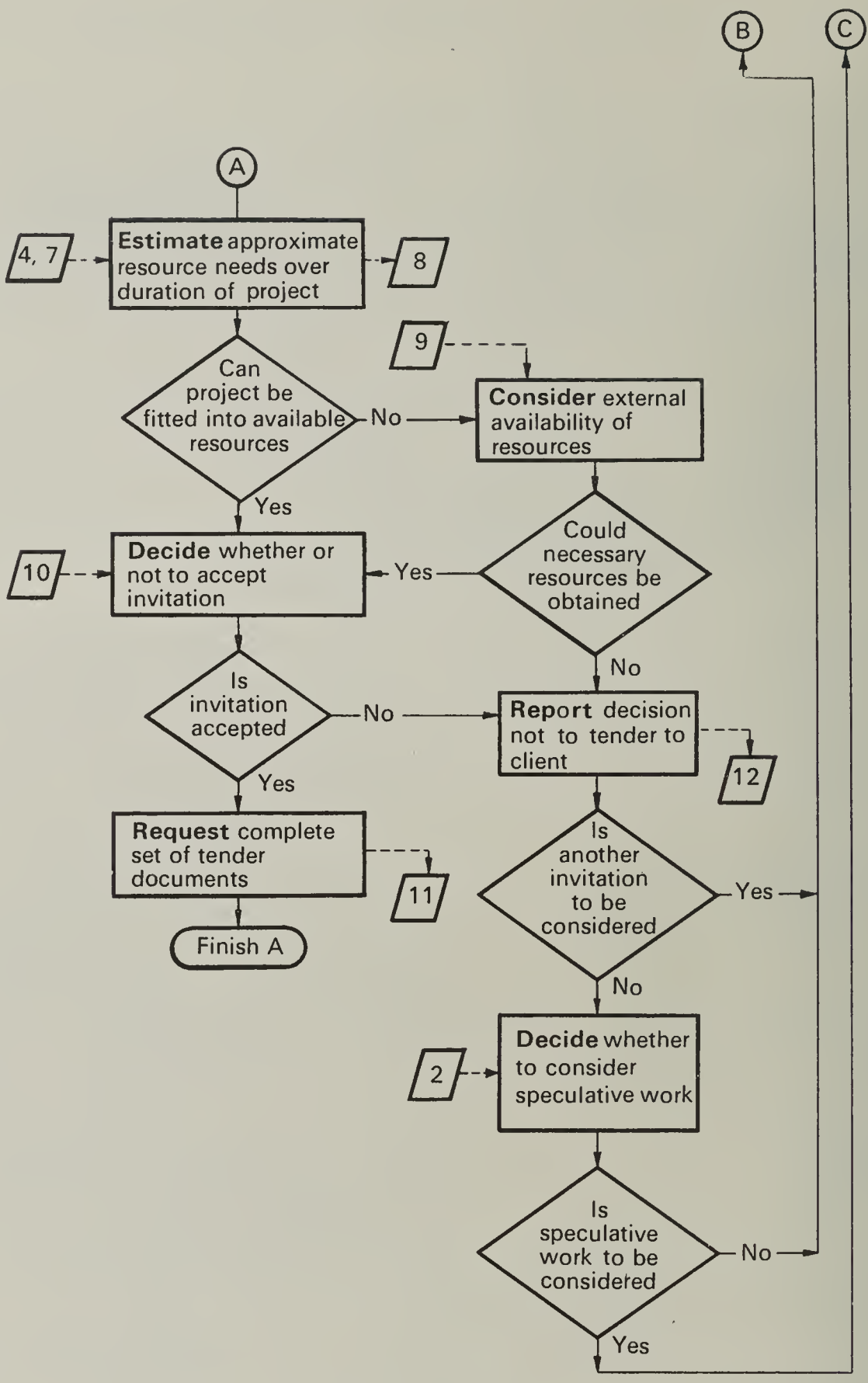
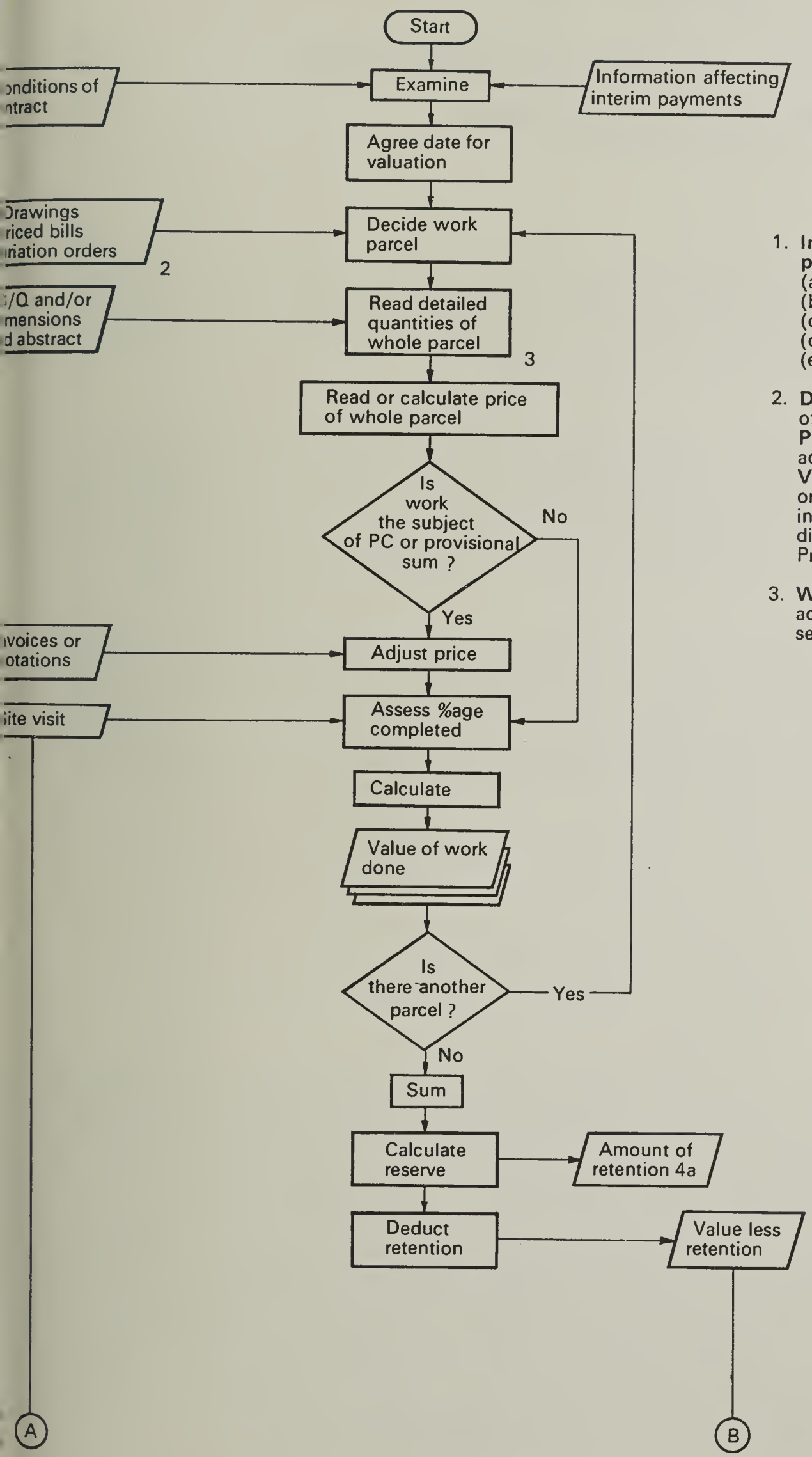


Figure 4 continued



re—5 **Preparation of valuations for interim payments** (An example of part of a mixed procedure)



1. **Information affecting interim payments:**
   (a) Intervals between payments
   (b) Period for honouring certificate
   (c) %'s and limits of reserves
   (d) penalty clauses
   (e) Cost claims within contract

2. **Drawings:** those used for preparation of B/Q.
   Priced Bills: priced bills of accepted tender.
   Variation orders: covering orders for all work varied including revised drawings, disbursement of PC and Provisional sums etc.

3. **Work parcel:** e.g. block, element, activity, operation, work section, bill item.

4a & 4b. Amounts held in reserve recorded for future accounting procedure.

Chapter 3

The rôle of data co-ordination in the building process

3-1 In Chapter 2 distinctions have been drawn between the functions which togeth make up building processes, and the procedures by which they are discharged. was stated—and the work described in this chapter shows—that each procedu can be described by a set of data operated on by a routine which, in this study, ha been expressed as a flow diagram.

3-2 Much of the study was taken up by the preparation and validation of a number procedures typical of building. This work, described in the present chapter, serve to validate the models assumed, to identify the roles played by information durin building processes, and the points at which some measure of data co-ordinatio could be expected to produce beneficial results, either by leading to a better use information already available, or to more economical working, or both.

3-3 In order to accomplish this, the team divided into sections each of which develope procedures in a defined area, and proceded to validate them by discussions wi practitioners in the industry. For this the team was augmented by consultants wh prepared routines and information schedules for particular procedures, and by thre officers from elsewhere in the Ministry who took the brunt of the interviews wi practitioners in their respective areas in addition to preparing schedules and routin for some procedures.

The sectors studied were:

Architectural design

Structural design

Mechanical and electrical services

Quantity surveying, product manufacture, merchanting

Construction

3-4 Those responsible for each sector prepared the routines and information schedul listed in Appendix D, often in consultation with practitioners, and subjected them scrutiny through extended interviews with practitioners. The sample of practitione was drawn on the basis of the team's knowledge of the industry in order to include reasonably balanced selection by size of organisation, by character of work unde taken, by geographical location, and by sophistication of technique and outloc Each practitioner was sent a sample of procedures relevant to his work and asked select one or more for subsequent discussion. The intention of these interviews w to ascertain whether the procedures developed could be applied in practice, wheth the information set out in the schedules identified the information actually sought sufficient detail, and what were the usual sources and vehicles of information. addition the interviews were used to examine current practice in order to asse whether any information used or generated is, or could be, generated or used b another participant in a project, thus leading to economy.

3-5 In addition, and in order to check the way in which the procedures fitted togeth the team carried out a simulated design exercise. In this, the design and constructio of a single storey factory with a multi-storey office block was simulated, followin the pattern of the RIBA Plan of Work for Design Team Operation. Members of th team assumed the roles of project manager, architect, specialist consultant et

Table 2 (1)

St	Col. 1
	Tasks (with sugge
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	Apprai
	Select
	Check
	Combi optima able to
	Detail
	To ob relate tion a
	Select
	Select
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	Verify constr
	Select
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	More c mecha in stag selecte
	Abortiv dating design

Stage/function

	Project information		Rôle of data co-ordination					
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
Tasks (with comments for improvements suggested by study)	**Input**	**Output**	**To classify = with relation to**	**To identify resources**	**To describe resources**	**To describe projects**	**To simplify procedures**	**To support information flow and achieve economy**
Inception (A) Feasibility (B) **To provide client with an appraisal and recommendation**								
Determine goals user requirements restraints	Client finance operations prejudices	Brief report on feasibility timing cost/benefit	Data retrieval using these relationships					Programme for this stage
Consider feasible solutions	Other planning economic		building regulations/ /site		Availability and price of critical resources			
Standard procedures for obtaining briefs should ensure completeness and save time. Briefs to be made available to all principals, contractor included.	Data from past projects, own and others		functional requirements/ /performance of systems					Combined design team highly desirable
Quality of feasibility report is determined by relevance, quality and availability of information.	Specialist reports		Performance/ /prices					
	Site survey		Functional systems/ /prices			Site survey	Input to survey calculations	
			Building types/ /prices					
Outline proposals (C) Scheme design (D) **To determine general approach and to select proposal(s) to meet requirements and constraints**								
Develop brief	Brief	Brief	Data retrieval using these relationships		Performance, specification, source price, availability of critical resources	Co-ordinates for site survey may make possible more detailed appraisal of cut/fill/ cost	Simulation studies on large projects. Standard inputs to procedures for system design of: environment structure access and circulation waste disposal	Programme for project as a whole, designed to monitor progress and information flow
Determine functional requirements	Site survey	Site plan	Regulations*/ /site		Compatibility of alternatives	Outline form recorded		Consider adopting systems already designed if that performance meets the requirements of the brief
Solve technical problems	Data from past projects, own and others	Sketch drawings Outline specification Cost plan Schedules of accommodation Room and other schedules	Functional requirement/ / performance/ /price			Room schedules initiated		
Appraise alternatives	Specialist reports		Functional system/ /Prices/ / running costs			Drawings related to systems		
Select solution	Advice from authorities		Regulations/ /building elements					
Check compliance with goals/restraints	Procedures for design of systems		Building elements/ /technical solutions/ /performance/ / prices/ /running costs					
Combined design team strengthens brief, makes optimal solutions possible with each specialist able to make contribution.			Cost plan in elemental form					
Detail design (E) **To obtain final decisions on every matter related to design, specification, construction and cost.**								
Select priorities and procedures	Brief, site plan, sketch design, cost plan	Drawings outline spec. modified cost-plan	Data retrieval using these relationships:	Critical commodities	Tò seek major resources with reference to function performance description specification source availability cost	Detailed 'form' developed: many routines require form to be stated in geometric terms	Standard inputs to and outputs from procedures for the design of: e.g. foundations structures mechanical services electrical services	Modified project programme to monitor flow of information
Select or develop solutions	Information from specialists, stockists and manufacturers	Revised accommodation and room schedules	building regulations*/ /building elements	Nominated products and suppliers		Drawings related to layout and location systems elements assemblies of components components sub-components		Management routine to make updated information available to team as a whole
Calculate solutions	Procedures for the design of systems and elements	Enquiries to nominated specialists	building elements//performance//technical solution//costs			'Room' schedules to show location of fittings and routes of services		Standard details, specifications, preliminary and preamble clauses, and unit quantities to avoid regeneration of information already available.
Verify compliance with requirements and constraints		Output tapes from specialists	Cost plan prepared in *building element* format					Dialogue between design team (including Q.S.) and specialists to make multiple use of data for: bar bending structural sections manufactured items such as: cladding roofing windows doors
Select commodities			Drawings prepared in *building element* x *trade* format					
Incorporate in design			Outline spec. in *trade* x *building element* format					
More complete design possible if specialists for mechanical and other systems appointed early in stage so that major items of plant can be selected								
Abortive work could be avoided by rapid updating of information held by each specialist designer								

**Regulations include bye-law and fire safety and planning regulations, Codes of Practice, Agrément Certificates, British Standards.

Table 2 (2)

Stage/function

	Project information		Rôle of data co-ordination					
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
Tasks (with comments for improvement suggested by study)	**Input**	**Output**	**To classify = with relation to**	**To identify resources**	**To describe resources**	**To describe projects**	**To simplify procedures**	**To support information flow and achieve economy**
Production information (F) Bills of Quantities (G) **To prepare production information in a form convenient to contractors and make arrangements for tender**								
Complete selection of commodities Agree performance and product specifications Draw, describe, and quantify work in terms meaningful to constructors *Proper structuring should admit adequate cross-referencing between documents*	Output of previous stage	Letter of invitation to contractors Letter of invitation to contractors Quotations from nominated specialists Drawings Bills of quantities (including the specification) Schedules	Drawings in elemental x trade format Bills of quantities* categorised by trade x building x work section x element x specification x root narrative x quantity† x list of commodities † allocated to locations * Specification embodied in bills of quantities	All commodities except those identified by a general or performance spec.	Performance or general specification in sufficient detail to select commodities	Drawings related to layout and location: systems elements assemblies of components components sub-components 'Room' schedules to show furnishings location of fittings and routes of services	Procedures for measurement using inputs from manufacturers and specialists (see E/11) procedures that call in details specification clauses, preambles and unit quantities	Modified project programme to monitor flow of information Management procedure to update information available to team as a whole
Tender action (H) **To obtain valid tenders based on the production information and to select a contractor**								
Despatch tender documents *Contractors* Send engineers to merchants and to sub-contractors Appraise construction problems Select construction method Determine activities Propose outline construction programme Extract data for pricing Estimate and tender *Architect & Q.S.* Appraise tenders and recommend appointment Analysis of lowest (3) tenders *Contractor* Record results *A more appropriate grouping of production information would simplify estimating and avoid abstracting data to obtain quotation.* *Preparation of outline construction programme and project proposal would assist the work of planner, if awarded contract.* *Merchants and other suppliers could price quotations quickly if codes were used to identify customer and commodities*	Acceptance of information to tender *Contractors* Tender documents (output Site visit Data from past jobs and from specialists Quotations Appraisal of local situation including firm's workload *Architect & Q.S.* Tender Priced bills of quantities Final cost plan *Contractor* Letter of appointment or rejection	Estimate Project proposal including Outline construction programme Profitability forecast Tender	Data retrieval using these relationships: Projection of work-load as cash flow / / capital commitment / / resource commitment Technical solution / / expenses Technical solution / / construction method / / recorded costs Construction method / / work element / / building element × location / / recorded productivity Mechanical plant / / output / / recorded costs Outline construction programme prepared in *activity* format Major resources categorised by: occupation / / performance / / availability Plant type / / performance / / availability Measured rates previously devised	Unique identification of all named resources and specified commodities Nuclear resources identified, e.g. cash flow management especially project managers major or specialist trades items of major plant factory capacity	Search to identify all commodities identified by performance spec. Major resources (see col. 6) described by performance location availability cost Selection of commodities with reference to (1) Meeting requirements (2) Availability (3) Price including discount (4) Credit facilities	Site visit noted on standard pro-forma with check-list *Activities* determined by *character* and *location* of work together with the *construction method* Proposals implicit in tenders stated in *project proposal* describing constructional techniques considered and adopted, level of productivity assumed and manning and sequencing of activities	Planning procedures to obtain feasible programme and to level resources Management procedures to calculate profitability	Modified project programme to monitor flow of information Coded identification of resources to simplify enquiries, quotations and flow of information between departments in contractors' organisation Cross-referencing between documents simplifies all reference to them
Project planning (J) **To prepare for construction (and for additional information) and allocate resources**								
Extent of task influenced by thoroughness of estimate: refer to *H* Send enquiries to merchants and own sub-contractors Appraise construction problems Select construction method Verify compliance with constraints Determine activities* Prepare construction programme Extract date for pricing to compare with estimate Prepare schedules for acquisition of resources *As H* *Sequential appointment of main and sub-contractors would make possible a better co-ordination of their programmes*	Production information (output F/G) Estimate and project proposal (output H) Resource availability Quotations from suppliers and own sub-contractors	Programme for construction Schedules for acquisition of resources Cash flow forecast Profitability forecast	Interest is centred on *activities* and *tasks;* all will be well if input is structured in this way. If this is not, the site management will have to rearrange the information provided Progress is reported and costing made in same terms as final programme and project proposal, i.e. activities x gangs x time x cash (inwards/outwards)	As *H* Uniquely identify: resources activities/tasks time	Selection of sub-contracting, operatives and equipment with regard to: performance availability cost When an unusual task is encountered reference made to commodity file or to specification to determine requirements for workmanship and acceptance	As *J* except that work-pieces and activities will be further sub-divided to make convenient tasks	Planning procedures to update programme and to level resources Management procedures to record and project cash flow and profitability Management procedure to ensure prompt updating of amended information	Modified project programme to monitor the flow of information Unique identification of resources, activities and time will promote information flow between site and head office, and head office and suppliers and sub-contractors Adequate cross-referencing between documents simplifies all reference to them

* Including management, site services, temporary works and attendance on others

Table 2 (3)

Stage/function

	Project information		Rôle of data co-ordination					
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
Tasks (with comments for improvement suggested by study)	**Input**	**Output**	**To classify = with relation to**	**To identify resources**	**To describe resources**	**To describe projects**	**To simplify procedures**	**To support information flow and achieve economy**
Operations on site (K) **To acquire and deploy resources to construct the project**								
Establish site, organisation and equipment Acquire resources management non-operative operatives sub-contractors construction materials commodities consumable stores plant instruct Obtain additional information Record progress Control progress to redeploy resources in the light of circumstances Make payments Inspect and accept completed work *Merchants and other suppliers could package commodities in 'work-piece' lots. Also if contractors were given priced delivery notices with allocation to activities, project costing would be more simple and more up-to-date* *Co-ordination of education and training—possibly by a modular approach—would achieve a better match with demands made on the industry, and if operatives were able to complete elements (structure, roofing etc.) to organisation of work would be simplified because gangs would have longer runs of unbroken work*	Production information (output F/G) Quotations from suppliers and own sub-contractors Programmes, resource allocation, schedules, cash flow and profitability forecasts (output J) Standard specifications and codes Additional information to complete or correct production information including Variation Orders	Progress reports Updated programme Updated resource allocation Quotations, delivery notices invoices, pay sheets, etc. Interim valuations and claims Cash flow record and projection Profitability projection	Data retrieval using these relationships: As *H*	As *H*	As *H*	Construction programme describe projects as work-pieces or identification x description of task x trade x element x quantity x work element undertaken as activities which add the additional information gang identify x resources x occupation operatives commodities plant materials x time earliest start latest visit x output required x operational instructions, especially safety	Planning procedures as *H*	As *H* Instructions to operatives engaged on all but repetitive tasks should be given more explicitly, including information about work-piece, resources and operation on an activity basis.
Completion (M) **To inspect, amend, accept completed work within conditions imposed by the contract**								
Inspect and appraise completed work Amend as necessary Accept Agree, measure and value variations Consider and settle extra-contractural claims Prepare and agree final account Hand-over project Inspect, amend and accept project at end of maintenance period *Negotiation to resolve conflict between* time *dependent costings of contractor and* quantity *dependent prices in tender could be made less difficult if construction programme, in activity terms, became part of contract documentation*	Production information (output F/G) Additional variation orders including information Construction programme Progress reports Interim certificates	Certificate of completion Final Account Report to client management *All* Profitability	As *K*	No new data introduced, reference back to *brief* and feasibility report by designers and to *production information, tender, construction programme* and *progress reports* by all participants				
Feedback (N)								
Feedback *must* occur throughout the course of every project to: Compare performance achieved with that required or predicted so that corrective action can be taken and to Add to data available to an organisation for future reference, or revision of standards (details, operational methods, cost data)			e.g. performance of each *'system'* as design proceeds *cost* of each system and *element* as design proceeds *progress* of project programme *tender* prices compared with *cost plan* *progress* on site compared with *construction programme* *cash flow* with predicted *cash flow* (and also for resources) e.g. *progress* achieved with *project and construction programmes* *final account* compared with *tenders* and with *cost plan* *performance in use* compared with predicted performance and with *brief* and *feasibility report* *productivity* achieved with that predicted *profitability* achieved with that predicted					

using the relevant procedures to study the interchange of information throughout the exercise.

3-6 Sectional reports (Appendix D) have been prepared by those in the team responsible for each sector which, together with their routines and information schedules, are to be published separately by the Building Research Station. Each report is self-contained and is likely to be of material assistance to any organisation or organisations concerned with the further development of data co-ordination.

3-7 Conflict between the need to maintain the flow of the argument through this report and the requirement for consideration of detailed points arises in this chapter especially. Any detailed discussion of the reasons why this or that function relies on this or that piece of information results in a series of static pictures of the process in which the progress of projects from one stage to another cannot be discerned; similarly a project-orientated argument assumes particular sequences of procedures which make generalisation difficult. In an attempt to avoid this dilemma, this chapter discusses each issue in turn, and the next draws together the conclusions stemming from each sector by relating them to the rôles played by information during the building process. Table 2 is relevant to the whole of Chapters 3 and 4; it sets out the functions discharged, and the information required to discharge them, in the context of the RIBA Plan of Work.

3-8 The team appreciates that some of the findings correspond with the obvious preferences of the industry. Unhappily the field trials showed convincingly that day-to-day practice falls far short of the ideal, and that many of the deficiencies of communication would be resolved if these preferences were put into practice. Because of this apparent gap between precept and practice, the report includes material that must be familiar to many practitioners.

3-9 The remainder of the chapter is devoted to a discussion of the findings of the field studies in each of the sections studied.

Architectural design

3-10 This sector considered two related subjects, the overall design of projects including the co-ordination of the work of specialist designers, and design procedures for specific functions.

3-11 Design starts with an assessment of the situation, to determine the requirements to be fulfilled, the means available, and the constraints that have to be observed. Thus prescribed, an *overall* design is conceived and appraised before it is developed in detail. This process, besides being typical of the early stages of whole projects, is encountered each time a designer considers, for the first time, the ways in which a functional system* or space* or a building element,* or a component* can be designed (in this context 'design' includes 'chosen') to fulfil the role required of it. In principle, design is concerned first with functional systems and layouts rather than building elements, and subsequently with elements rather than components and finally with components. In practice, designers cannot follow this sequence exactly, because of the necessity of ensuring that components critical to the performance of the projects exist.

3-12 When the procedures in this sector were being developed it was thought that no single representation of the whole process of project design could describe the variety of circumstances encountered, particularly during the briefing stage, and attention was directed to procedures for the design or selection of components. Subsequently it was seen that procedures for layout involving different briefs required similar information inputs and resulted in similar outputs, and that procedures for the design of the various functional systems had similarities with each other, although their selection and the relative priority given to each was individual to each project.

3-13 Further, it was seen that the procedures for layout, functional system and component design all had much in common, and could be represented in one basic design

* See Glossary

Fig.—6 The basic pattern of design procedures

Non-project information	Operations in this design procedure	Project information	Operations in the stream of project
That generally available, but organised for retrieval by speciality.		That generated specifically for the project and potentially available to all in the project team	
Means: Previous solutions, available techniques, products etc. Design methods, Regulations, Recommend-ations External constraints		Existing conditions, The brief; Instructions & restraints from within the project team; Designed work—the form and specification of the project to date	

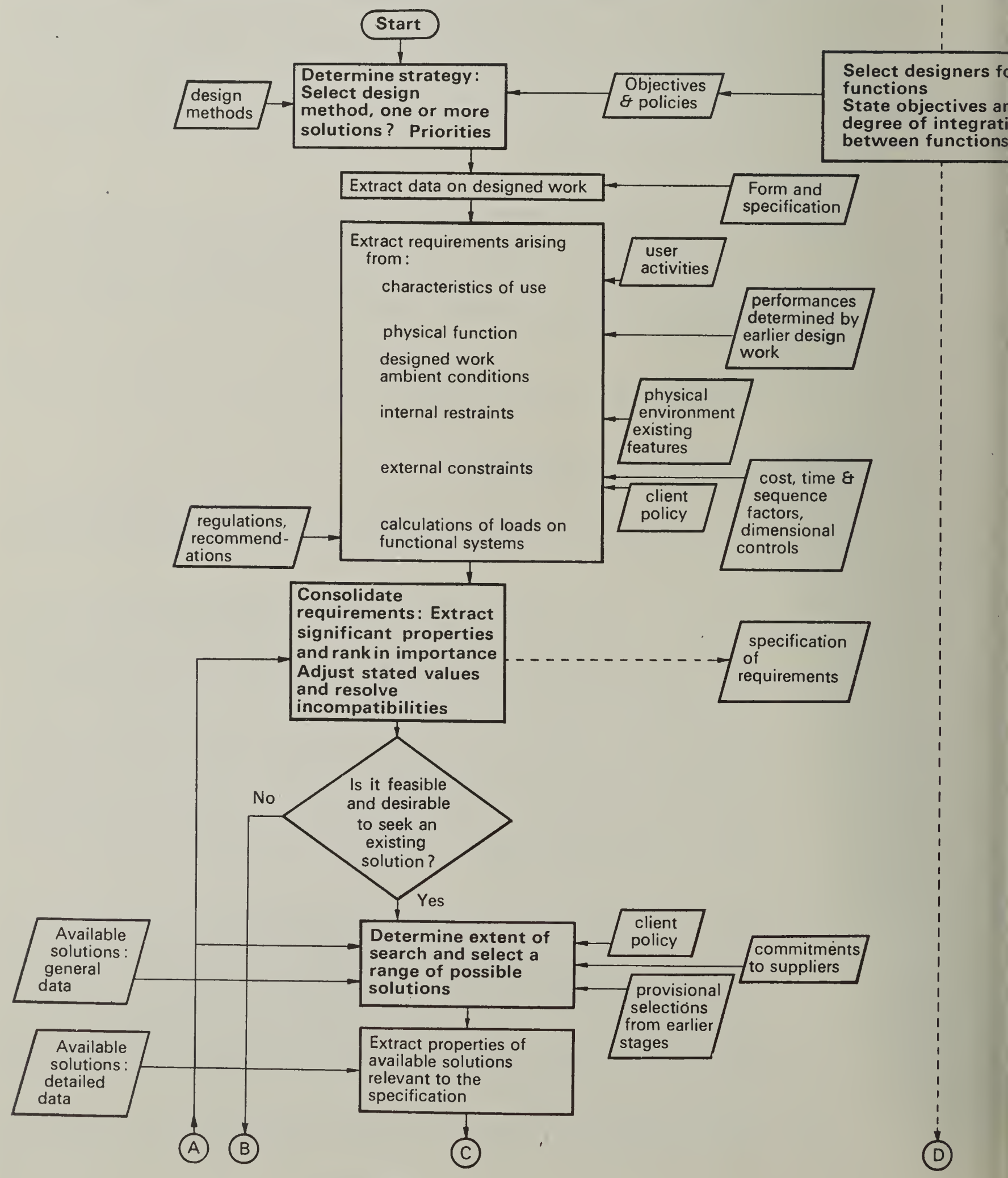
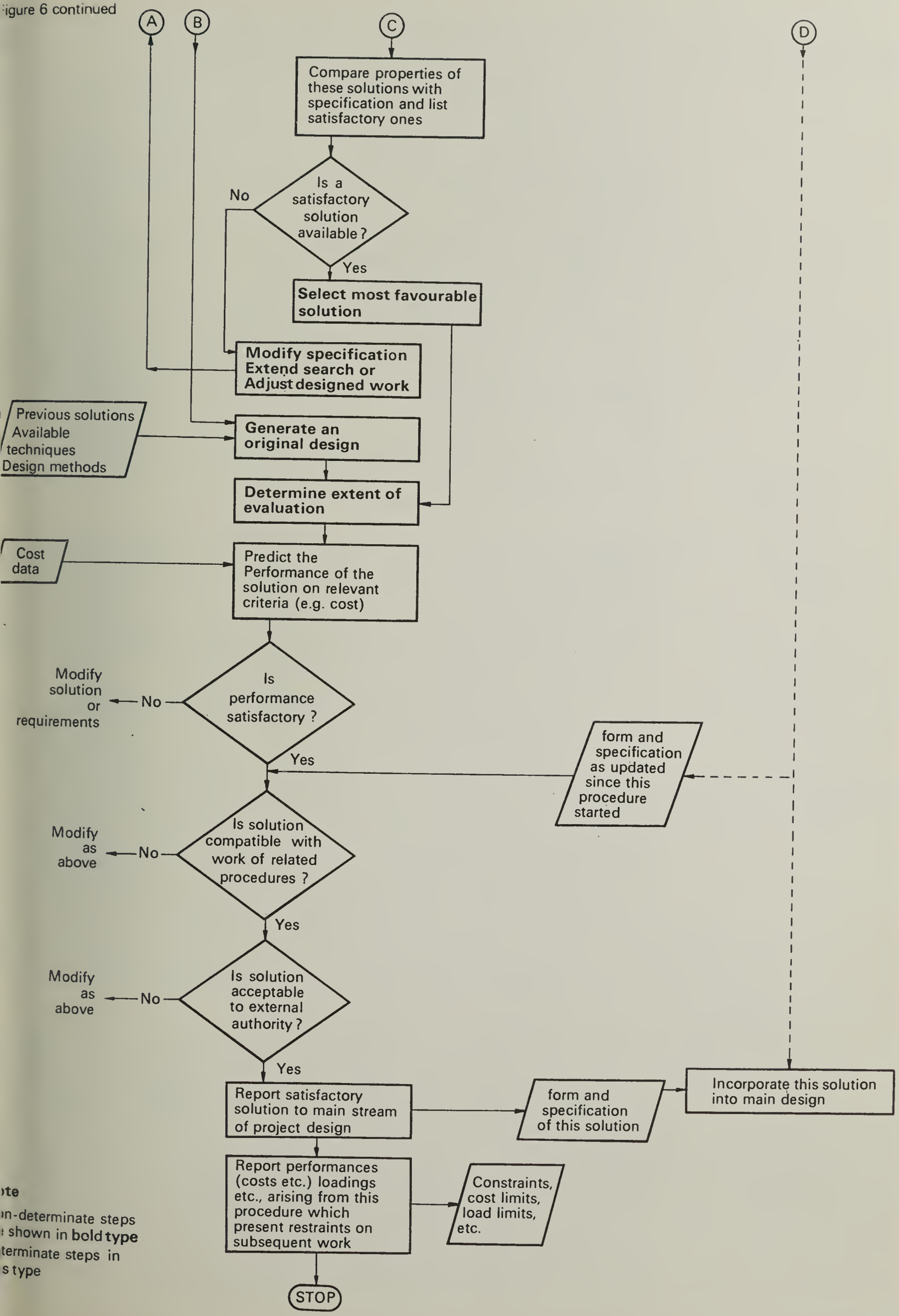

Start
Determine strategy: Select design method, one or more solutions? Priorities
design methods
Objectives & policies
Select designers fo functions
State objectives ar degree of integrati between functions
Extract data on designed work
Form and specification
Extract requirements arising from:
characteristics of use
physical function
designed work ambient conditions
internal restraints
external constraints
calculations of loads on functional systems
user activities
performances determined by earlier design work
physical environment existing features
client policy
cost, time & sequence factors, dimensional controls
regulations, recommend-ations
Consolidate requirements: Extract significant properties and rank in importance Adjust stated values and resolve incompatibilities
specification of requirements
Is it feasible and desirable to seek an existing solution?
No
Yes
Available solutions: general data
Determine extent of search and select a range of possible solutions
client policy
commitments to suppliers
provisional selections from earlier stages
Available solutions: detailed data
Extract properties of available solutions relevant to the specification
A
B
C
D

Figure 6 continued


A
B
C
D
Compare properties of these solutions with specification and list satisfactory ones
Is a satisfactory solution available ?
No
Yes
Select most favourable solution
Modify specification Extend search or Adjust designed work
Previous solutions Available techniques Design methods
Generate an original design
Determine extent of evaluation
Cost data
Predict the Performance of the solution on relevant criteria (e.g. cost)
Modify solution or requirements
Is performance satisfactory ?
No
Yes
form and specification as updated since this procedure started
Modify as above
Is solution compatible with work of related procedures ?
No
Yes
Modify as above
Is solution acceptable to external authority ?
No
Yes
Report satisfactory solution to main stream of project design
form and specification of this solution
Incorporate this solution into main design
Report performances (costs etc.) loadings etc., arising from this procedure which present restraints on subsequent work
Constraints, cost limits, load limits, etc.
STOP

ote

on-determinate steps
shown in **bold type**
terminate steps in
s type

procedure (Fig. 6). It will be seen that the procedure commences with a statemen of the objectives and the interaction between the present and other procedures. Th next step is for the designer to select a strategy, including the design method, th priorities that should be given to different aspects of performance, the extent t which the solution should be evaluated, and when and how the evaluation shoul be made. In practice this stage is usually effected whilst the data necessary for desig to proceed is collected and this includes the properties required, the ambient con ditions, and internal and external constraints. One of the more important decision made by designers is whether to seek an acceptable solution from existing solutions or to develop a new solution. This decision cannot be made rationally until a searc has been completed of the available solutions, a task that could be greatly simplifie by a modest degree of data co-ordination, for this would both extend the presen areas of search and also enable designers to identify solutions with similar perform ances, although described differently. If it is decided to generate an original solutio this will also require data retrieval to provide information and details of suitable sub components—for there is no reason why these should not be drawn from existin rather than original solutions. The general procedure is completed by predicting th performance of the overall solution and comparing this with the requirements an constraints already determined. Only then should data regarding 'this solution' b added to the project data.

3-14 Routines and information schedules were prepared for procedures chosen t represent carcassing, dividing and finishing elements, and services and externa works. These are listed in Appendix D.

3-15 A study of outline procedures showed that the information required for differe projects is remarkably similar, although in each project the degree of detail for eac type of information would differ, and the stages at which detailed information c one kind and another became important would vary from project to project. Therefo there is no need to distinguish between the information requirements for differe projects; it is only necessary to devise search procedures to enable designers to as for progressively more detailed information.

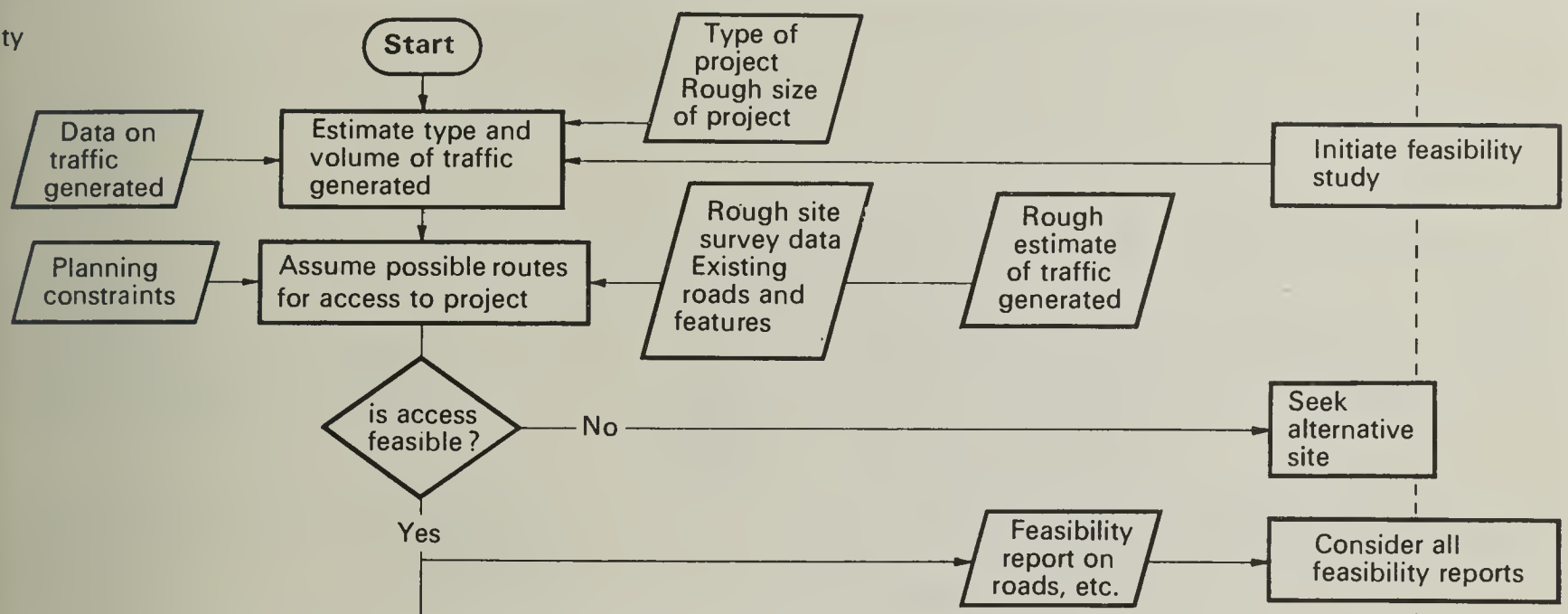
3-16 Once the form of the project has been determined, procedures can be applied to th design of functional systems. Here again, the priorities selected by designers a likely to have a decisive effect upon the degree of detail of information needed, an the order in which it is sought. For instance, design of the internal environment shoul not proceed until a choice has been made as to the relative priorities to be given t day-lighting, to the standard of thermal insulation, to the expenditure on heating, an to the internal noise environment. The choice may be made as a result of an ove riding requirement, or of an examination of costs-in-use. Depending upon th balance struck, the demand for relatively detailed information will follow in order t ensure that the aspect of performance given high priority is likely to be satisfie by the selected solution. A similar situation arises during the execution of th procedure for the design of roads and paths, in which designers must decide on th extent to which the design of this system should influence the overall layout of th project. The procedure developed (Fig. 7) illustrates the way in which interest shif as design proceeds from the general to the particular.

3-17 As design progresses there is a continuing need for information of many kinds. Som of this is peculiar to 'this' project, perhaps contained in the brief, or in the site surve or in drawings, schedules or specifications. Much of the information is more genera being drawn either from the conspectus of knowledge, or from information structure to inform designers about the performance of past projects, functional systems building elements, or from information about materials, products, and component Information directly relevant to designers needs to be classified so as to make retriev possible along paths more directly related to the building process and thus facilitate feedback both within and between projects. Feedback within projects necessary to ensure that designers are made aware whether objectives (e.g. pe formance and use) are met. Feedback between projects may entail collection of da by firms, or by institutions (the RICS Cost Information Service, for example) dissemination in technical journals (e.g. the project reports in the Architects' Journal

ɟure—7: A procedure for the design of roads and paths

ɔn-project information	**Operations in this design procedure**	**Project information**	**Operations in the main stream of project design**
at generally available, t organised for retrieval speciality eans: Design methods evious Regulations, lutions, Recommenda- ailable tions :hniques, External ɔducts constraints :.		That generated specifically for the project and potentially available to all in the project team. Existing conditions, The brief Instructions and restraints from within the project team Designed work—the form and specification of the project to date	

ɜge B
asibility


Start
Type of project Rough size of project
Data on traffic generated
Estimate type and volume of traffic generated
Initiate feasibility study
Planning constraints
Assume possible routes for access to project
Rough site survey data Existing roads and features
Rough estimate of traffic generated
is access feasible?
No
Seek alternative site
Yes
Feasibility report on roads, etc.
Consider all feasibility reports

ɜge C
ɪtline
ɜsign

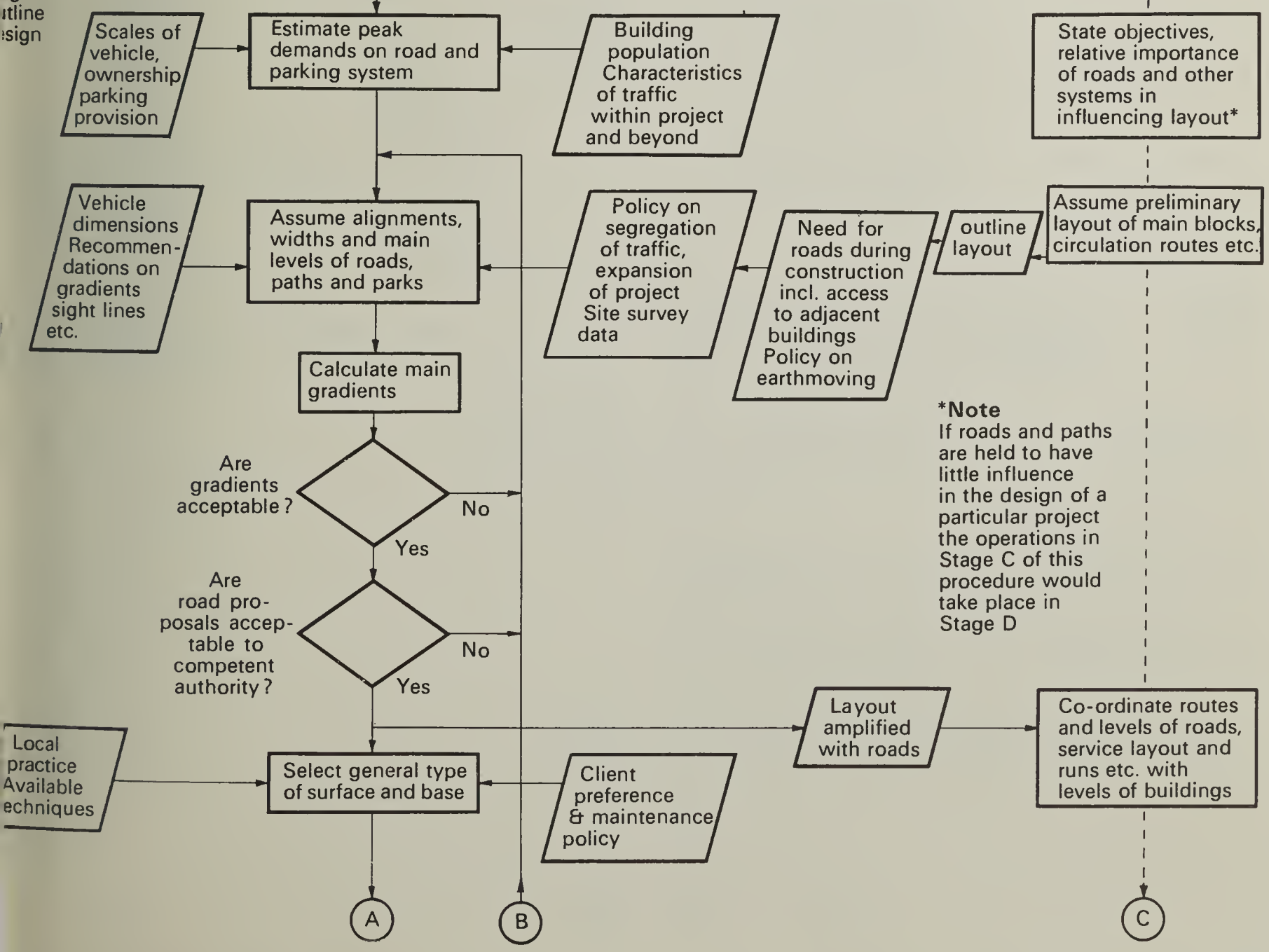

Scales of vehicle, ownership parking provision
Estimate peak demands on road and parking system
Building population Characteristics of traffic within project and beyond
State objectives, relative importance of roads and other systems in influencing layout*
Vehicle dimensions Recommen-dations on gradients sight lines etc.
Assume alignments, widths and main levels of roads, paths and parks
Policy on segregation of traffic, expansion of project Site survey data
Need for roads during construction incl. access to adjacent buildings Policy on earthmoving
outline layout
Assume preliminary layout of main blocks, circulation routes etc.
Calculate main gradients
Are gradients acceptable?
No
Yes
Are road pro-posals accep-table to competent authority?
No
Yes
*Note
If roads and paths are held to have little influence in the design of a particular project the operations in Stage C of this procedure would take place in Stage D
Layout amplified with roads
Co-ordinate routes and levels of roads, service layout and runs etc. with levels of buildings
Local practice Available echniques
Select general type of surface and base
Client preference & maintenance policy
A
B
C

Figure 7 continued

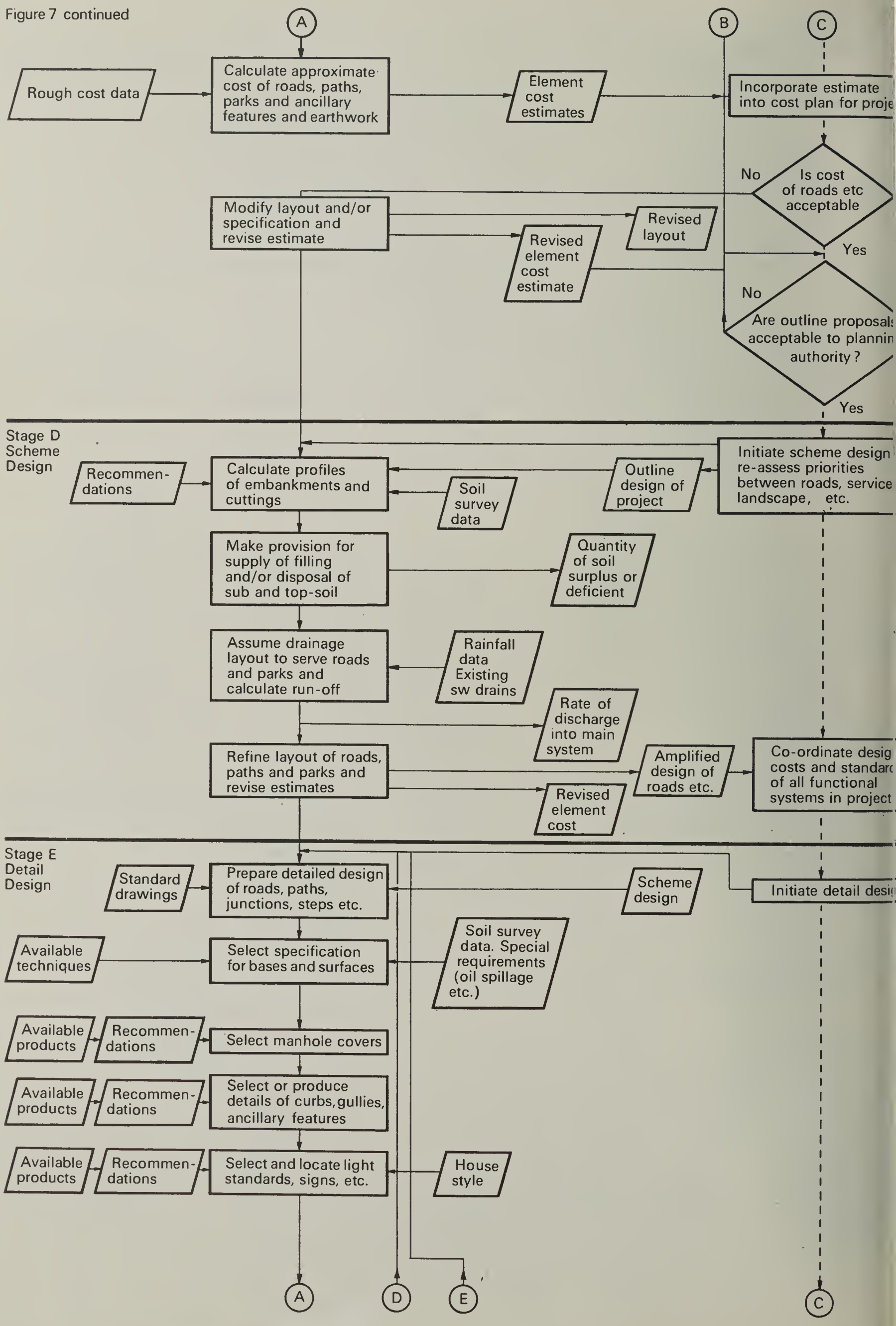
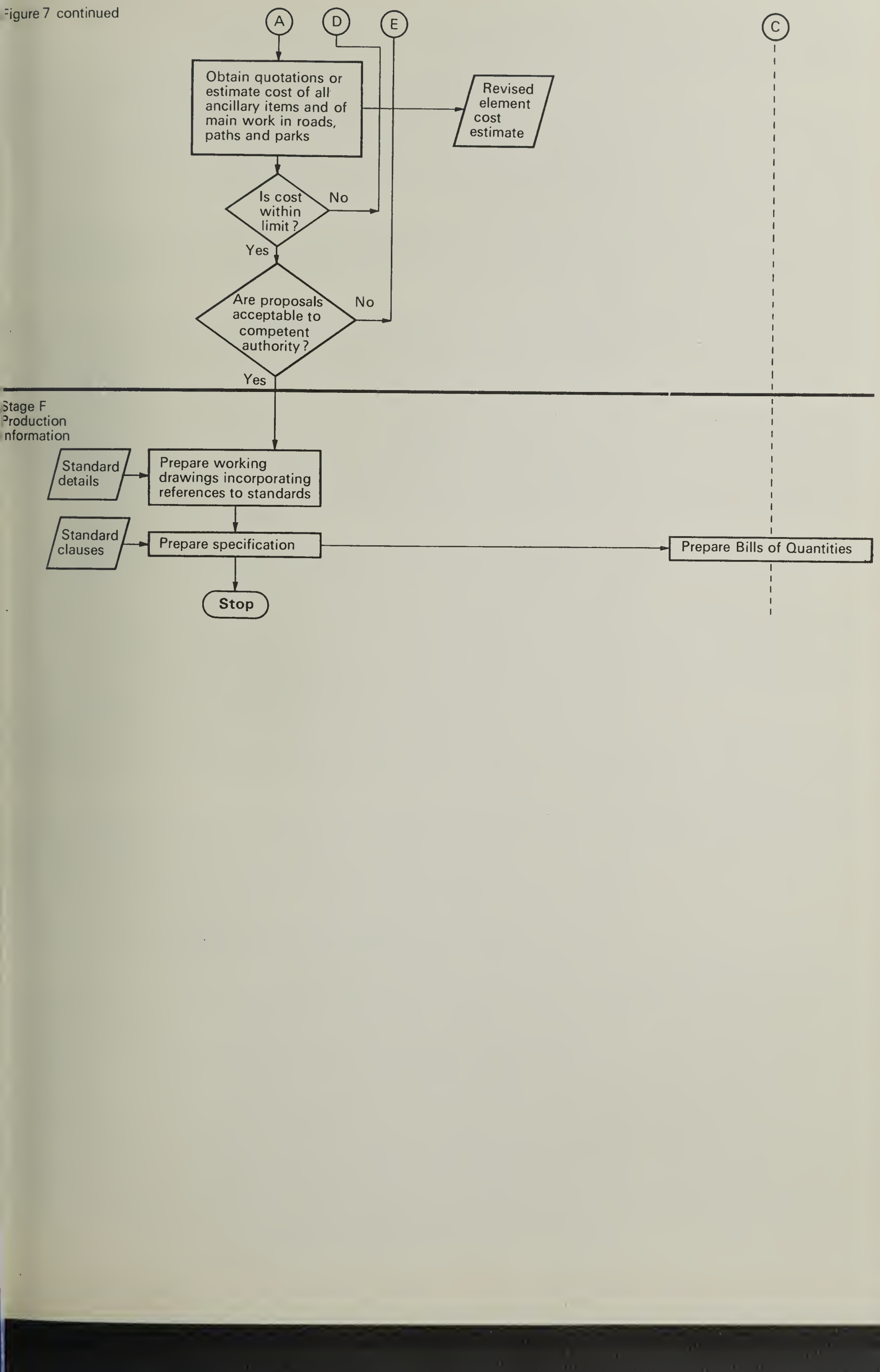

A
B
C
Rough cost data
Calculate approximate cost of roads, paths, parks and ancillary features and earthwork
Element cost estimates
Incorporate estimate into cost plan for proje
No
Is cost of roads etc acceptable
Modify layout and/or specification and revise estimate
Revised layout
Revised element cost estimate
Yes
No
Are outline proposals acceptable to plannin authority?
Yes
Stage D Scheme Design
Recommen-dations
Calculate profiles of embankments and cuttings
Soil survey data
Outline design of project
Initiate scheme design re-assess priorities between roads, service landscape, etc.
Make provision for supply of filling and/or disposal of sub and top-soil
Quantity of soil surplus or deficient
Assume drainage layout to serve roads and parks and calculate run-off
Rainfall data Existing sw drains
Rate of discharge into main system
Refine layout of roads, paths and parks and revise estimates
Amplified design of roads etc.
Co-ordinate desig costs and standar of all functional systems in project
Revised element cost
Stage E Detail Design
Standard drawings
Prepare detailed design of roads, paths, junctions, steps etc.
Scheme design
Initiate detail desi
Available techniques
Select specification for bases and surfaces
Soil survey data. Special requirements (oil spillage etc.)
Available products
Recommen-dations
Select manhole covers
Available products
Recommen-dations
Select or produce details of curbs, gullies, ancillary features
Available products
Recommen-dations
Select and locate light standards, signs, etc.
House style
A
D
E
C

Figure 7 continued



Whatever the means, effective feedback entails adequate classification of informatio and a consistent statement of the performance achieved.

3-18 The other type of information often sought during the consideration of functiona systems was to answer questions such as 'Do solutions exist that satisfy the require ments and the constraints?' and requires either an operational model of the syster together with a means of manipulating data referring to preferred solutions, or categorisation of solutions with regard to their performance. Both presuppose a goo theoretical understanding of the system being studied, and this is likely to be a important as the method of data co-ordination employed.

3-19 If it is accepted that the sequence of each procedure can be specified independentl and that the development of these procedures will be accomplished only slowly, th prime requirement would seem to be categories for filing and retrieving data abou performance.

3-20 Routines concerned with the design or selection of components and product followed the general procedure introduced in paragraph 3-13 with the exceptio that the schedules of information placed less emphasis on general issues and mor on the description and performance of components, methods of assembly, finishing prices and running costs, and compliance with standards and regulations. In th case the question asked is, 'Which of the possible solutions most adequately satisf the requirements and constraints?', a question asked, implicitly or explicitly, wher ever designers select a material or component. Therefore much of the volume o specialised information the industry uses is related to 'things' that make up projec (e.g. to materials, products and components) rather than to concepts.

3-21 Information about commodities* is seen as next in importance to 'functional systems Except for overall design, and for the design of systems, neither of which are muc concerned with information about commodities, most other functions—selectio detailing, specifying, measuring, estimating, planning, buying, receiving, assemblin accepting—are concerned with commodities or with other resources. Standa specifications, trade literature, contract and commercial documents all descrit various aspects of the materials, products and components required to comple projects. Designers are concerned with performance, properties, price, dimension methods of jointing; contractors with sources, availability, form, discounts, transpo and packaging, and working properties; and the need to exchange information abo commodities alone could justify the initiation of a measure of data co-ordinatio reaching right across the industry and into the associated supply and manufacturir industries.

3-22 Information passed between procedures was found to describe the form of a projec to be about commodities, to give instructions or constraints affecting subseque procedures, or to confirm that these instructions or constraints had been met. addition all procedures drew on information contained in the brief and on informatio about existing conditions, whatever these were. At the commencement of projec the latter are probably the client's requirements, the physical environment, the existir services etc. As projects proceed procedures draw on a progressively narrower ran of information, much of which is given by the design already completed.

3-23 All the evidence pointed to the advantage to be gained from a good brief by members of the design team. Much of the information that could be part of a brie including details about the site and adjoining properties and about a client's prefe ences, exists from the outset of a project, and does not depend on any subseque design work. In some instances, clients who frequently commission buildings prese designers with well-developed briefs which clearly describe the functions require the criteria to be satisfied and the priorities to be observed. Often, however, th development of a brief is a considerable task to which designers contribute ar which, like other aspects of design, moves from general to particular considerations as a clients' requirements become more clearly defined. In these circumstances, the is a lot to be said for the conception and feasibility stage to be separate from th project proper, thus facilitating the preparation of an exhaustive brief to be mad available to all principals brought into a project.

* See Glossary

3-24 All participants wish to know about the 'form' of the project. On the one hand this defined the context of their work as did no other type of information; on the other, quick notification about changes in form and dimensions avoided abortive work, and abortive work is expensive to designers.

3-25 Drawings fulfil this rôle, and are likely to do so for some years to come. There is obviously scope for adopting a greater measure of standardisation with regard to the content and presentation of drawings [9]. Nowadays much information is duplicated on drawings, in addition to being repeated in specifications and in Bills of Quantities, a habit that designers find expensive, and contractors irritating. Greater standardisation of drawings, properly co-ordinated would also make more feasible the widespread use of standard details, and here the United Kingdom has much to learn from Scandinavian practice [10]. In the long term, computers may oust drawings from their privileged position on account of the facilities provided to retain, amend, manipulate and recall graphic information [11]. Also as has been emphasised by Patterson [12], visual displays are a more familiar medium to architects than are numeric inputs and outputs, and can avoid the need for explicit coding. Finally, remote terminals would make possible notification to all concerned when any participant had amended a design in such a way as to affect the work of others.

3-26 There is a case for the preparation of room schedules, in which all the information about a room—size, finishes, windows, electric services, heating, lighting, ironmongery etc.—would be listed. This came up also very strongly on the M and E side as well and might well be worth further study. The schedules would be started once the rooms were defined and would be added to throughout the design by all participants [13].

3-27 It is also clear that a timed programme* for the whole design process is as crucial to the efficient execution of design as it is for construction.

3-28 This section has considered neither the form of information passed on to later stages of the building process, discussed under Design Realisation (3-97 *et seq*), nor the vehicles of communication, schedules, drawings, specifications, Bills of Quantities, instructions and trade literature; these are common to all sectors and are considered separately in Chapter 5, Practical Considerations.

3-29 The extended treatment of this, the first of the design sectors, has enabled discussion on the remaining design sectors to concentrate on issues that are critical when viewed from the standpoint of a specialist designer. No attempt has been made to reproduce material already mentioned since this would not have advanced this Report. Consequently some of the specialist sectors are discussed only briefly. This in no way diminishes their importance either to individuals or to those who will implement the recommendations of the main Report.

Structural engineering

3-30 The team found a valid distinction between the rôle played by structural engineers during the outline and feasibility stages of design and subsequently when the detailed calculations were made and the structure designed. During the early stages of design, structural engineers have a wide range of choices, and can exercise many of the options open to general designers including determining the range of solutions that are to be considered and the methods of evaluation. Isolation of structural engineers from the remainder of the team during this stage of design was judged to limit the contribution that could be made, a contribution that is further restricted by the poor feedback of costs by quantity surveyors. Structural engineers are generally kept informed of the progress of the cost plan until their contribution to the design is completed, but from that stage onwards it is unusual for further information to be made available to them—either the estimated cost of the project as a whole, or analyses based on tender prices. To this extent they are isolated from the cost consequences of their decisions which, if available, would enable them to fulfil their rôle more effectively.

* See Glossary

3-31 During the detailed stage of design, structural engineers require little information other than the brief, the site survey, the form of the building and as much as is known about loading conditions. Criticism was expressed of the lack of information from M & E engineers at this stage, e.g. on the sizes and weights of major pieces of equipment, and it was suggested that this stemmed from the tendency to leave the selection of the equipment until after the main contract had been let. Clearly, in the absence of precise information, structural engineers are forced to make pessimistic assumptions.

3-32 There is an essential requirement for input and output to computer programs* to be prepared in standard ways so that programs can be used widely by structural designers, so far as this is compatible with the security of information confidential to individual practitioners. The Institution of Structural Engineers has been active in this field, having laid the foundations for future development by the publication, 'Standardisation of Input Information for Computer Programs in Structural Engineering' [14]. This is work that should continue, and perhaps be extended to include the further standardisation of details, especially the connections between members for all types of structure and for constantly recurring structural details. These could lead to savings within the offices of structural engineers and to the transmission of information in a form useful to quantity surveyors and to suppliers. The latter would benefit if outputs for reinforcing bars or for structural members could trigger inputs to numerically controlled machines for marking-out, cutting, bending, etc. [15].

3-33 Communications between structural engineers and other participants mostly take the form of drawings and specifications, and notes for further work by quantity surveyors. Drawings do not present problems different from those encountered in other sectors, although it was suggested that pictorial drawings would be more meaningful to site operatives than the more usual orthographic projections. Structural engineers have a special responsibility for ensuring the stability of structures, and often must insist that site supervisors follow a particular sequence of erection and temporary supports; this might be helped by cross-references between drawings and specifications with an accepted code identifying those parts of the structure which should not be erected before consulting the specification. Communication with quantity surveyors could be improved by data co-ordination, in particular when computer programs design rather than analyse, and a need was seen for sub-programs in a form that quantity surveyors could use to generate quantities, descriptions and specifications. A step in this direction has been made by the publication of British Standard 1478:1967 for reinforcing bars, a standard that gives code references to bars of standard shapes, and to their dimensions. This work could usefully be extended.

3-34 Structural engineers saw immediate advantages from computer applications e.g. more thorough analysis of the effect of alternative loadings was expected to detect areas of possible over-stressing which, although not dangerous, might otherwise lead to unsightly cracking, but were anxious that computers should not inhibit the use of experience and judgment during the early stages of design.

3-35 Three important practical consequences of data co-ordination and the application of computers were foreseen. Good management procedures are essential to ensure that up-dated information is exchanged in an orderly fashion. Joint (or closer) working, although possibly leading to better overall solutions, may make the allocation of responsibility more difficult. Finally, these methods of working are likely to lead to a redistribution of the work-load within professional groups, and to make possible the progressive cheapening of the design process and thus reduced fees. Such matters are relevant to the introduction of data co-ordination and the extension of computer usage, although not within the competence of this study.

3-36 There was also a requirement for data co-ordination of a different type from that previously considered, *viz* establishing conventions that could be observed by a group discharging a technical function. These, in the case of structural engineers, would deal with moments, loads, forces, the geometric properties of structural sections, and methods of analysis. Such conventions could be developed alongside

* See Glossary

gure 8
procedure for
sign of environment

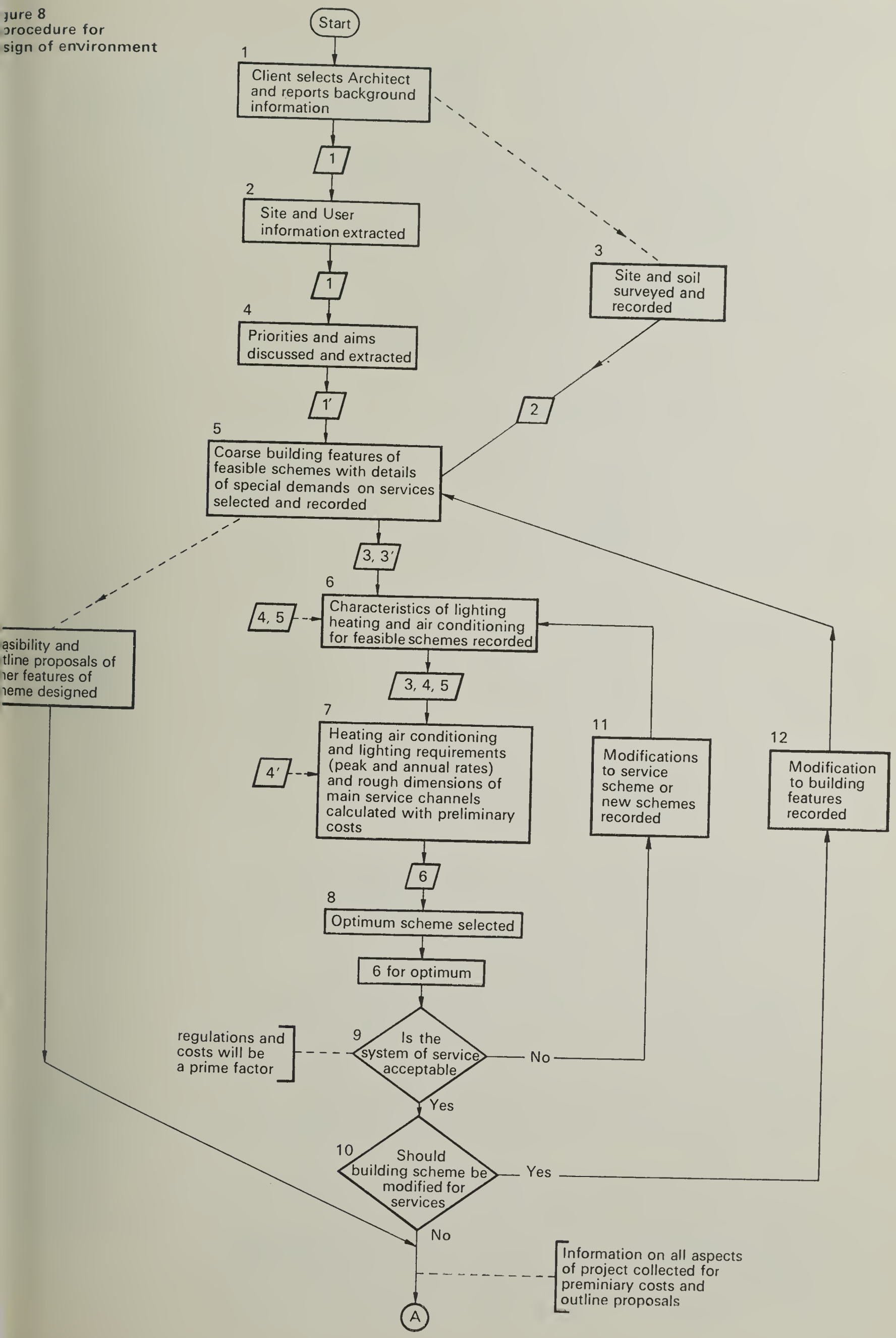
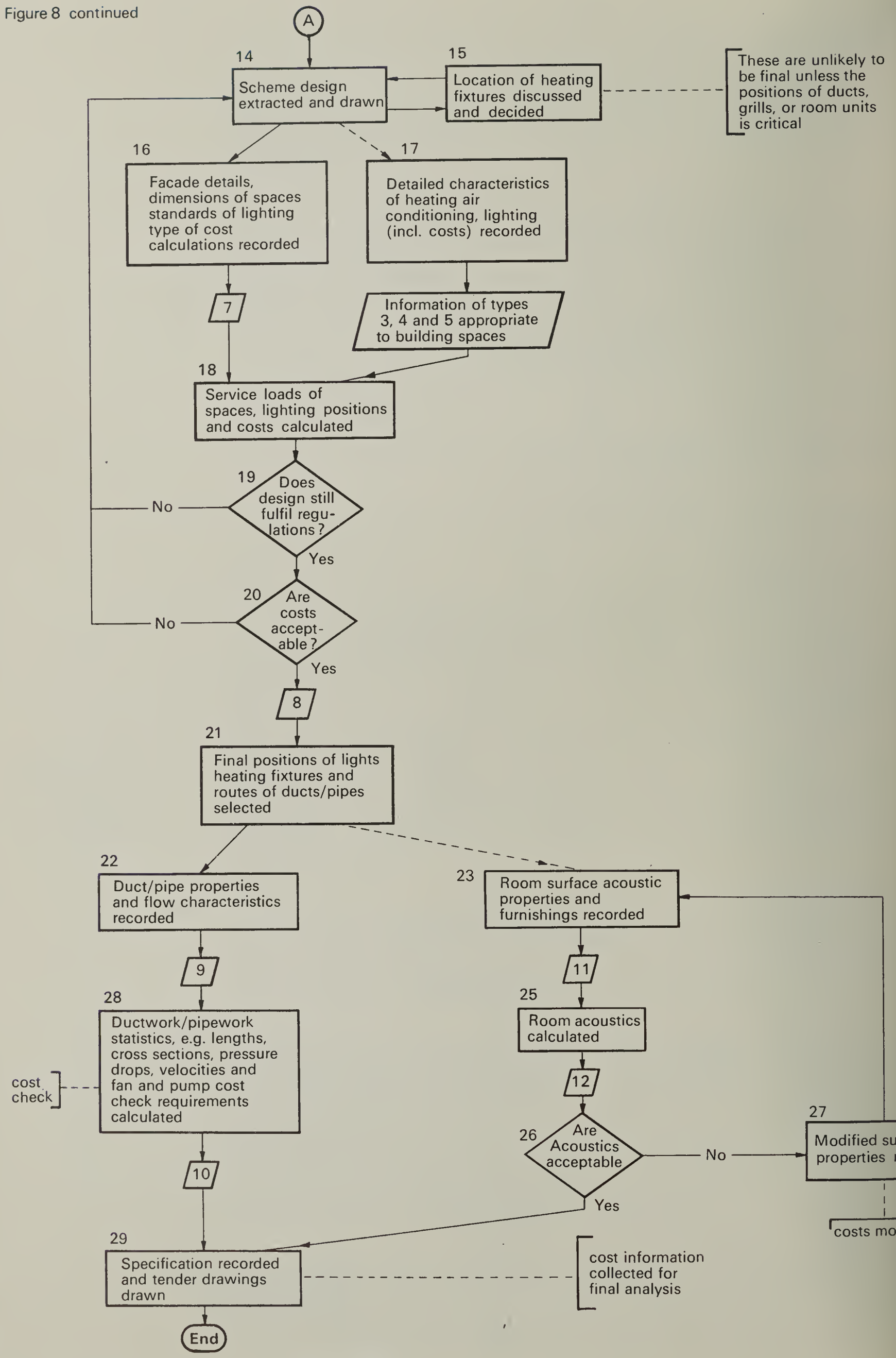


Figure 8 continued



computer application, being extended and modified as the number of computerised procedures grew. Such conventions would assist more economic manual working, besides being of material assistance to those engaged in education and training.

Mechanical and electrical engineering services

3-37 Notwithstanding the fact that the design of the environment is of close concern to the architect, it is treated here because of its interdependence with M and E work.

3-38 Initially a procedure for the design of environment (Fig. 8) was prepared which showed the essential interaction between a system and the project of which it forms part by including the iteration processes by which modifications are introduced until acceptable solutions are reached. This emphasised the well-established need for close co-operation between the members of the design team.

3-39 The general environmental design procedure also introduced the need for data from past projects, particularly in the early stages of design when performance of the whole functional system is considered rather than detailed characteristics and performance of individual items. Data co-ordination would assist the collection of this information by providing a ready facility for handling feedback information from past projects.

3-40 The sub-division of the general environmental procedure into the individual M and E procedures is of interest because it shows how extensive procedures can be concisely illustrated by flow diagrams, without distorting the essential features of a procedure or its inter-relationship with other procedures (Fig. 9).

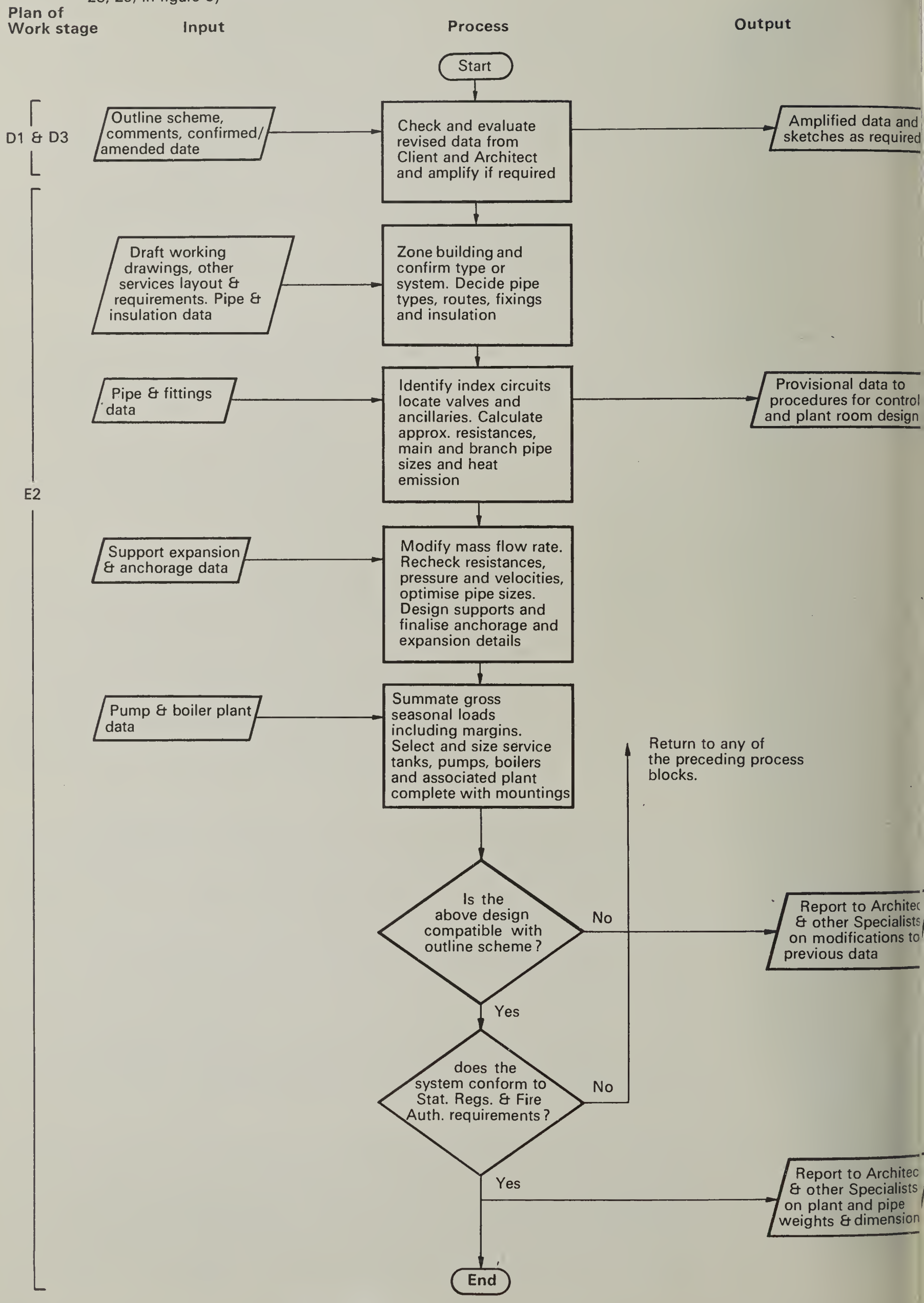
3-41 Field testing within this sector emphasised the harmful consequences and the lack of co-ordination that stem from the late appointment of specialist designers to design teams. An essential contribution of M and E designers was seen to be in the feasibility and scheme stages of design, when projects are fluid, and when questions critical to the eventual performance of the project as a whole can be considered and discussed. This is particularly important in the M and E field where an awareness of operating costs in addition to capital and maintenance costs is an essential requirement and one which can radically alter the overall design philosophy. All too often specialists were appointed when decisions already taken prevented them from contributing to an improvement in the performance of projects overall, a situation that no amount of data co-ordination and coding will improve.

3-42 The sequence of the RIBA Plan of Work, within which the procedures were prepared, provoked a response from practitioners that a substantial amount of design occurs well after the tender stage. This is because final plant details (weights, dimensions, fixings, etc.) are not available until the specialist contractors have been appointed. This point also affects other specialists such as structural engineers who, as noted earlier, commented unfavourably on the lack of information of this sort at the time required to finalise their designs. Once again it will be noted that data co-ordination will not cure some of the major restraints on the flow of information between participants.

3-43 Mechanical and electrical engineers found that clients' briefs were often deficient in essential data, or that the data given were not sufficiently reliable. Again, this emphasises the advantages that would stem from different arrangements for preparing briefs.

3-44 Electrical engineers were especially concerned with the growing tendency of clients to delay final selection of equipment that affects electrical loading until relatively late in the construction phase. Often this leads to over-provision of cabling to meet the heaviest likely loadings, and restricts the contribution electrical engineers can make to the giving of value for money over the project as a whole. It was stated that in practice the electrical designer often has to accommodate his work to that of other designers, partly because the electrical services are relatively more flexible than

Figure—9 Pipe sizing including boilers and pumps
(expansion of parts of processes 21, 22, 28, 29, in figure 8)


Plan of Work stage
Input
Process
Output
Start
D1 & D3
Outline scheme, comments, confirmed/ amended date
Check and evaluate revised data from Client and Architect and amplify if required
Amplified data and sketches as required
Draft working drawings, other services layout & requirements. Pipe & insulation data
Zone building and confirm type or system. Decide pipe types, routes, fixings and insulation
Pipe & fittings data
Identify index circuits locate valves and ancillaries. Calculate approx. resistances, main and branch pipe sizes and heat emission
Provisional data to procedures for control and plant room design
E2
Support expansion & anchorage data
Modify mass flow rate. Recheck resistances, pressure and velocities, optimise pipe sizes. Design supports and finalise anchorage and expansion details
Pump & boiler plant data
Summate gross seasonal loads including margins. Select and size service tanks, pumps, boilers and associated plant complete with mountings
Return to any of the preceding process blocks.
Is the above design compatible with outline scheme?
No
Report to Architec & other Specialists on modifications to previous data
Yes
does the system conform to Stat. Regs. & Fire Auth. requirements?
No
Yes
Report to Architec & other Specialists on plant and pipe weights & dimension
End

others and partly as a result of late appointment when other services have already been laid out. It was suggested that in these circumstances the formal and early appointment of a services co-ordinator would assist communications and produce economy, notably by avoiding delays on site whilst incompatible solutions are sorted out.

3-45 Suggestions were made to develop the room schedule already used by some architects (and referred to earlier) so that surface areas would be included together with main dimensions, thus reducing the possibility of error and undue repetition of calculations. Further development could then include the addition of floor loading, distribution of furnishings and equipment and environmental data, etc. to show the total requirement of each room. This—consistently updated and circulated—would go some way towards meeting the general complaint of specialist designers that they are not informed about decisions made by other designers, especially the routes taken by services. In the absence of this information all specialists tend to 'hang-back' to the last possible moment in order to avoid abortive work.

3-46 Contractors interviewed were also critical of the variable standard and quality of specifications they received and many voiced similar complaints about drawings. The suggestions made were that there should be nationally accepted general specifications to which all contractors would work, supplemented by brief particular specifications prepared for individual contracts. Electrical contractors preferred drawings to be reduced in number and to show as many electrical requirements as possible on one set, and both electrical and mechanical contractors wanted drawings to show any interface problems with other trades.

3-47 Procedures developed (Fig. 8, 9) show a similarity with those for structural engineering, in that once a 'system' is selected, the routines follow a recognisable sequence of calculations. Mechanical and electrical engineering design procedures conclude, however, with the selection of materials and components, a function that is reflected in the information schedules.

3-48 The information schedules have requirements similar to those for architectural design for data about commodities, and a commodity file would be a good vehicle for carrying information for identifying, specifying, and stating performance of products. Practitioners believed that standard forms of presentation of manufacturers' data would expedite design, detailing and the selection of equipment, besides simplifying comparisons between products with similar performances and purposes.

3-49 Mechanical and electrical engineers had a requirement to locate enclosures—rooms —within projects. This, the first mention of locational information, is discussed in greater detail later because this is one of the items of information contractors need to know.

3-50 M and E engineers seldom use Bills of Quantities, to which there are strong objections from the specialist contractors. Even when used, bills are more often prepared by the design engineers than independent quantity surveyors and although future development visualises the possibility of producing a bill or at least a schedule of material, this is seen more as a natural consequence of the design function than as a separate activity.

3-51 The specialist M and E routines cover the installation stages as well as design, by including programming, planning, labour and material estimating, costing and analysing. Although the general treatment of these aspects broadly follows the same lines as in the building sector of the industry, there are differences which have been fully discussed in the specialist reports. Subsequent remarks in the main report on QS and construction activities have accordingly been concentrated on the builder's rather than the specialist contractor's approach to these aspects.

Construction

3-52 In this sector attention was focused on project selection, estimating, project planning control and costing, because it seemed that these are most likely to be affected by data co-ordination; overall management of construction companies, not differing greatly from those in other sectors of industry, is likely to make use of general commercial codes. The routines were prepared with a formally organised building firm in mind and, suitably modified, they might be suitable for all sizes of such firms. It is expected that working principals of small building firms will benefit considerably from data co-ordination, although it is not expected that they will find much need to follow procedures.

3-53 This section concentrates on project planning and control because these, together with estimating, are the activities that distinguish construction from other industries. Moreover, they determine the demands made on production information, and on the type of feedback that can occur to management and to designers. Consideration of design realisation (including the preparation of estimates), is left to a later section because the work entailed must depend on the requirements for information of the functions of construction, estimating, planning and control.

3-54 At the planning stage there is a requirement for detailed production information of a kind that is not entirely necessary during estimating. Furthermore, the present arrangement of contracting firms separates estimating from planning, so that the former can use the information available in present tender documents. Hence the information requirements of planning and control are central to data co-ordination and it is necessary that they should be discussed first.

3-55 From the standpoint of data co-ordination, there are similarities between the contractor's planning activities and the architect's scheme design stage, and site operations and detailed design. In both, the interest is first in fairly broad matters ('Which of the possible solutions best satisfies the requirements and constraints?') and later in more specific details ('How exactly shall I achieve this requirement?').

There is, as with design, a progression from the general to the particular, from less to more detail. Perhaps the biggest difference is the almost universal separation at present of the functions of estimating, for tender purposes, and planning, for contract purposes. Few contractors have adequate feedback arrangements for site experience to affect estimating, and in most firms the management of contracts works in ignorance of the thinking that has gone into the estimating. This organisational problem would, of course, be well on the way to a solution if the steps toward data co-ordination proposed as a result of this study were implemented. Data would be classified in ways that would be meaningful to more participants in the building process.

3-56 Contractors have a brief in the form of the production information, adding to this information from within contracting organisations and in turn from other sources (material suppliers, sub-contractors etc.). However, contractors have only a limited responsibility for producing information for consumption by other organisations. Therefore a contractor's interest in data co-ordination is mostly directed to structuring the information essential to a firm's operational methods, including provision of feedback. Feedback within projects will be required to alert management to the need for action when the progress and costs achieved depart too far from prediction; feedback between projects to inform management, estimators and planners of the levels of productivity and cost actually achieved. The twin requirements to ensure a flow of information matched to site operations and to provide feedback are the dominant theme of the following sections.

Planning

3-57 The function that is fulfilled at present is to match information received from designers with the records and experience of the contracting organisation, in order to select a suitable technique to make good use of the contractor's resources, and to obtain a feasible programme within the contractor's estimated cost.

3-58 Following an appraisal of the project information, probably prepared during the estimating stage, the first step is to select the construction method.* In part this choice will be determined by the design, in part by the contractor's experience and by the available resources. To this extent contractors have a freedom of choice akin to that exercised by designers, calling for the exercise of experience and judgement informed by such costs and performance records as exist. Not too much should be expected of these records, because many factors affect the outcome of a project, including local circumstances, the availability of labour, relationships between the parties concerned, the number of variations etc. Data co-ordination is not of itself likely to play a major rôle in improving the accuracy of this cost information, but, through the use of suitable categories, should make it more accessible for all purposes.

3-59 Major projects will justify formal appraisals of alternative constructional methods. Although most of the examples that readily come to mind are civil engineering rather than building construction, e.g. open-cast mining, extensive earthworks, formal appraisal is also justified for complex buildings e.g. those with deep basements, or for repetitive construction e.g. industrialised housing. In these circumstances, simulation studies are almost certainly justified, but again these exercises depend on a proper understanding of the operational consequences of the various alternatives, together with adequate feedback of production information of a kind that is listed in the information schedule attached to the procedure for the appraisal of alternative working methods (Fig. 10).

3-60 Having selected one method, whether by hunch or by systematic appraisal, the remainder of the job of the planner falls into three phases: firstly, defining the work to be done at each stage of the construction; secondly, estimating the resources and the elapsed time required to execute each stage, and calculating the overall resource requirements; thirdly, calculating the resulting costs and comparing these with the estimate.

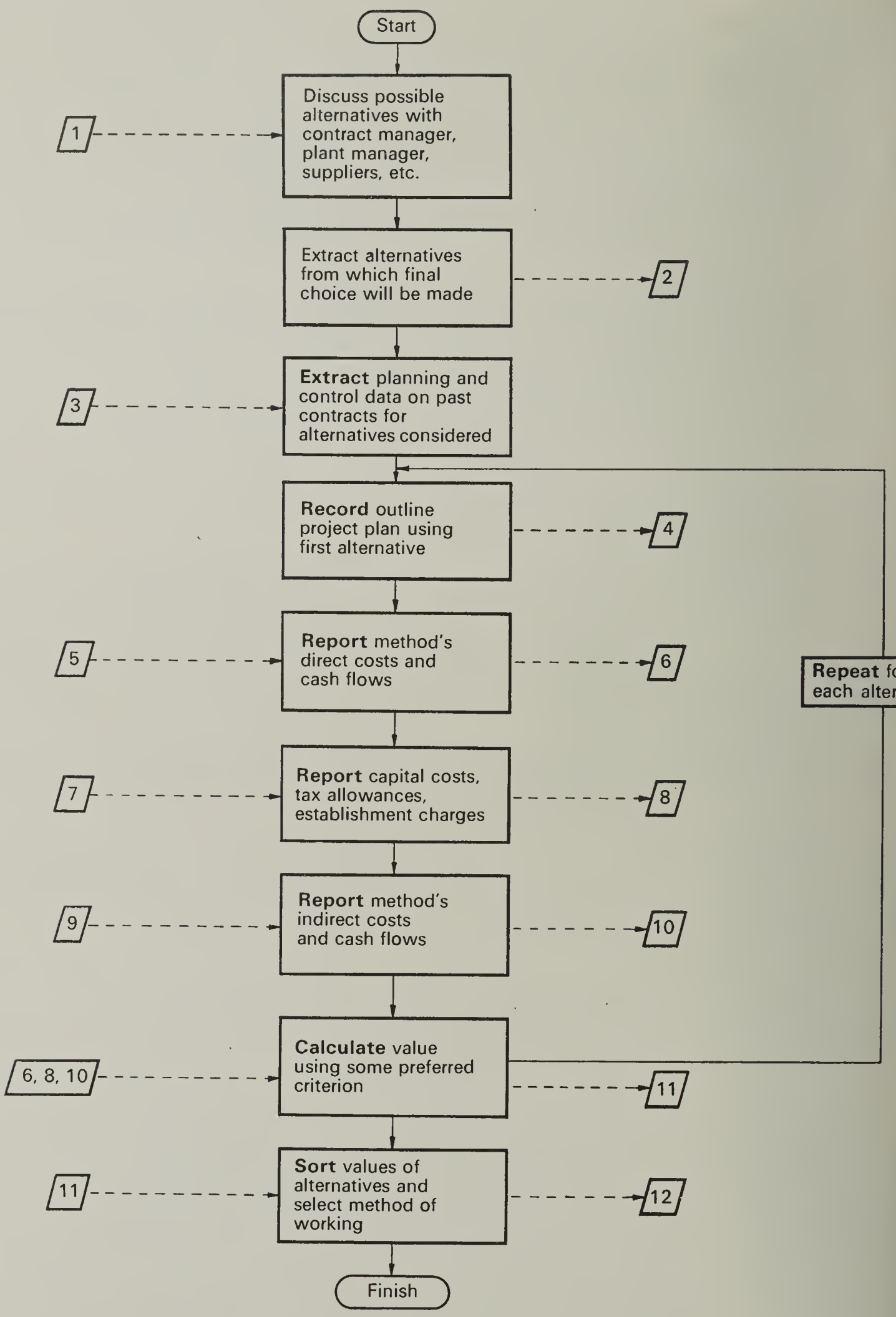
3-61 The central problem is specifying the work to be done at each stage, called for the purpose of this report a 'work-piece'*, or a stage of construction to which resources may be allocated [16].

3-62 Definition of the work-piece may be resolved into two parts; defining the boundaries, and specifying the character of the work to be done so that this can be matched to a set of resources.

3-63 As planning proceeds from general to detailed considerations, the size of the resource considered and the time for which an allocation is made become progressively smaller. For example in multi-storey in-situ concrete construction, the construction of the structure may be undertaken by a composite gang consisting of plant operators, concretors, reinforcement benders and fixers, carpenters and labourers, a gang that will be fully employed on this task until it is completed, and this is all the information required at an outline stage of planning. Subsequently, however, it will be necessary to devise a more detailed programme to determine the interaction between the work of the sub-gangs, in order to establish a cycle of construction that will avoid excessive non-productive time and give a more precise idea of the number of operatives required. For these purposes the extent of a work-piece will change with the sub-gang; for the concreting gang the work-piece will be the extent of the concrete that can be placed in a shift or in a day, whilst for the reinforcement and shuttering gangs the work-piece might be an individual wall or floor bay if these two gangs have to work closely together. Finally, if the number of repetitions made such an exercise worthwhile, there might be a need further to analyse the work-piece in order to determine e.g. the maximum size of formwork that might be used, or the size of skip that is most appropriate to the task. There are, therefore, two conflicting requirements, the need to have some unit of measurement to which production information can be attached, and the requirement to analyse work-pieces into progressively smaller elements as planning proceeds from general to detailed considerations.

3-64 A planner has to produce a schedule of activities* showing the number and type of resources required and the time required to complete each work-piece. To do this,

Figure—10 Procedure for appraisal of alternative methods of construction



CORRECTION

ne Information Schedule on pages 33 and 34 is incorrect and
replaced by the information given as follows:—

nformation Schedule for Figure 10

Appraisal of alternative working methods

Start This routine may be applied to the planning of an entire project, but is more likely to be a Section of 'outline planning and costing' or 'detailed planning' where it is referred as OP 8 and DP 5.

Ref	Name	Identifying Term	Characteristic	Source of Input or Form of Output
AM1	Specification	of selected project or section of project	dimensions, location, materials time available, description of work to be done	Bills of Quantities, contract drawings, other specification, contract conditions
AM2	Method Statement	selected alternatives for (section of) project	plant, equipment and labour needed, approx duration	past records, consultation with managers etc.
AM3	Progress	for selected alternatives over past contracts	plant, equipment and labour used, actual duration, productivity	site reports from past jobs
AM4	Work programme	outline plan of work for section of project	dates, durations, numbers of men, plant and equipment needed per time period	chief planner
AM5	Costs	direct costs of each resource	total cost per unit per time period	from suppliers, wage rates etc.
AM6	Costs	estimated total direct cost for this method	cash sum; flows per time period	estimator
AM7	Costs	capital cost of each resource	cash prices, taxes, allowances, distribution of losses, depreciation period	from suppliers, government regulations
AM8	Costs	estimated total capital cost for this method	cash sum; flows per time period	estimator

Ref	Name	Identifying Term	Characteristic	Source of Input or Form of Output
AM9	Costs	indirect costs of this method	site overheads, management costs, services etc.	past records etc.
AM10	Costs	estimated total indirect cost of this method	cash sums; flows per time period	estimator
AM11	Value	of method's cash flows	net present value, rate of return, net profit etc.	criterion decided by company policy
AM12	Method statement	of preferred alternative	as AM2	as AM2

FINISH proceed to re-enter OP or DP at references OP 8 or DP 5.

Building Research Station
February 1969.

LONDON: HER MAJESTY'S STATIONERY OFFICE

ıformation Schedule for Figure 10

Detailed Planning

Start This routine follows 'outline planning and costing' and the work involved depends on the degree of pre-tender planning carried out. It is assumed that a contract has been signed, or (for speculative work) the decision to proceed has been made.

Ref	Name	Identifying Term	Characteristic	Source of Input or Form of Output
DP1	Specification	of project	dimensions, locations, materials specified, time available	Bill of Quantities, contract drawings, other specification, contract conditions
DP2	Specification	of site for project	dimensions, access, conditions, services	from survey maps local enquiries etc.
DP3	Specification	of project	further information in same form as (DP1)	from meetings with client and advisers
DP4	Work programme	outline construction programme for entire project	list of major operations against calendar scale	outline planning routine (OP7)
DP5	Experience	of planning and programming	appraisal of working methods	site records from previous contracts. Routine PC may use routine 'Investment appraisal of alternative working methods'
DP7	Method statement	for each section of project	list of resources and method for each section	chief planner
DP8	Operational breakdown	for project	list of operations, titles and sequences	in form of network
DP9	Specifications	for each operation in project	dimensions and quantities of materials or description of work to be done	from 'detailed planning' routine (DP1) and (DP8)
DP10	Utilisation	of each resource on similar past operations	gang sizes, durations, productivity, learning	site records from previous contracts
DP11	Productivity requirement	of selected gang size	quantity fixed per unit time period	site records from previous contracts from routine progress control
DP12	Duration	of each operation	duration in convenient units	
DP13	Work programme	detailed programme for entire project	operation dates, floats etc.	in form of bar chart or analysed network
DP14	Resource requirement	for each operation of project	number of items required each period of operation, operation times	
DP15	Resource requirement	for each resource of project	continue as (OP16)	
DP16	Availability	of external resources at times required	number of units available per time period	suppliers and subcontractors

DP17	Resource details	for each resource needed	minimum order quantities, delivery periods and arrangements, payment periods	suppliers and subcontractors
DP18	Delivery schedules	for each resource needed	number of units to be supplied each time period	buying department
DP19	Orders	for each resource needed	total order quantity and delivery schedules, prices	suppliers and subcontractors, previous quotations (OP19)
DP20	Experience	of site planning		
DP21	Specification	of each activity in project	whether to be bonussed or not, activity duration, location and sequence, dimensions, quantities and description of work to be done. Resource requirements	discussion with site agents, trades foreman, bonus clerk
DP22	Cost	direct cost of each resource	cost per unit per time period etc.	from plant department, costing department, materials suppliers etc.
DP23	Cost	estimated direct cost of activity	cash sum and cost per resource	
DP24	Work programme	detailed programme for project	activity dates, floats, resource schedules	
DP25	Work programme	detailed pre-tender programme for entire project	operation dates, floats etc.	from routine 'outline planning' (OP 15)
DP26	Specification	of project	any further revisions to specification in same form as (DP1)	client's adviser
DP27	Cost	total estimated direct cost of project	cash sum, cost of each resource	from (OP21)

Proceed to enter 'bonus target' and 'multiproject resource scheduling' if necessary.

he must choose the resource and gang size appropriate to the activity bein undertaken, and estimate the productivity likely to be achieved on site. To estimat productivity makes considerable demands on judgement, but can be greatl helped by properly recorded results from previous projects. When this is done th calculation and assignment of the earliest and latest start and finish dates for eac activity completes the initial planning of the project. Improvements may be sough by routines to level out resource usage and to reduce non-productive time, routine that do not call for additional information.

3-65 The numerous tasks that are not related to any particular work-piece must also b listed as activities. Adequate allowance is normally made for site handling gangs, fo supervision, for housekeeping, and for attendance on specialists. Evidence suggest that the increasing use of specialists can make heavy demands on contractors operatives particularly when the specialists require intermittent servicing. Here ther is a dilemma that will not be resolved by data co-ordination, as such; main contractor cannot adequately programme work and estimate the extent of attendance unt apprised of the intentions of all major sub-contractors; similarly sub-contractor

cannot declare their intentions without some foreknowledge of the likely construction programme. Again this is a situation calling for an examination of existing contractual procedures in order to relate these procedures more accurately to the information requirement of those who have to accept the risks implicit in contracting.

3-66 There is, of course, the obvious need to identify projects, areas within projects, buildings within areas and storeys within buildings, and this information would go a long way towards solving some of the problems of planners. For many purposes, however, a finer degree of locational information is required; for example to determine the limits of the amount of in-situ concreting that can be placed, or to check the sequencing of a number of specialists through an area congested with services, or when information is required about finishings and fittings to be put into any room.

3-67 The function of planning is completed after a check is made to ensure the compliance of the plan with the constraints surrounding the contract; delivery dates of major materials, installation of major specialists' work, and, of course, estimated cost.

3-68 The construction programme enables schedules to be prepared to show the allocation of resources and the dates by which these should be acquired. Materials schedules usually require contractors to take-off the materials needed for each activity, thereby largely duplicating the work already performed in the preparation of Bills of Quantities. Work at the Building Research Station has shown that this information can be provided in trade terms by quantity surveyors, especially in bills arranged on an operational basis[1, 2]. This task adds to the cost of taking-off, and is yet another matter with practical implications that will have to be solved if data produced at one stage are to be made available in a useful way to later stages of the building process. Later developments, equally relevant, are activity bills and other Bills of Quantities in which the work to be done is allocated in a way that will be operationally meaningful.

Project control

3-69 A programme prepared on the lines indicated will allocate resources to activities. That is, equipment, operatives, commodities and contractors' materials, will be allocated to tasks to be carried out at specific locations, at specific times (given the latitude implied by earliest/latest start and by earliest/latest finish). Project control will be facilitated, therefore, if the same data structure is retained, and if resources are identified by the activity to which they are intended to be committed, and by the times at which the commitment is intended to take place. Given this it is possible to co-ordinate planning, progress control, and costing.

3-70 Control includes taking those measures necessary to ensure construction of the project on the lines indicated by the programme. The first step is to acquire resources sufficiently early to ensure their deployment at the time intended. Operatives present special problems particularly when sites are isolated or when they are located in areas enjoying a boom in construction work. Forward projections of resource requirements are essential for the completion of an isolated project job, but when projects are in areas in which retention of labour is uncertain, effort must be expended constantly to redeploy the labour force in order to complete activities essential to orderly progress. Similar arguments apply in the case of sub-contractors.

3-71 Resource schedules provide information for ordering the delivery on site of mechanical equipment, commodities, and materials. It would be an advantage if the information given by contractors to materials suppliers and manufacturers were to include the activity number and its location in addition to the project, the location of the site, and the required date of delivery. If this additional information were to be returned to the contractor on delivery notices and invoices, it could then be merged with progress and cost control procedures.

3-72 Similarly the inclusion of an activity number on progress, bonus and payroll documents would permit resource usage to be stated in 'actual' terms that could be used to monitor productivity and to calculate cash flow.

3-73 Hence progress recording and control is simplified if all information required a generated on site is grouped according to the activities to which they relate, includi activities for work on the site as a whole and for temporary construction. Costi (comparing actual expenditure with that intended) poses more difficult problen Some stem from the difficulty of reconciling interim valuations based on Bills Quantities with payments for materials, sub-contractors, wages and salaries. Son stem from the fact that payments for the various resources (weekly and month wages, payments to suppliers, interim and final payments to sub-contractors) a receipts (interim and final receipts from clients, credits) occur at different times.

3-74 Difficulties of the first kind can be overcome if Bills of Quantities are arranged so th the material is or can be rearranged in activities; operational bills, for example Difficulties of the second kind can be partly overcome if estimates and costi records keep elements of cost that are time-dependent separate from those that a once-and-for-all payments, or part-payments, because, if this is done, the differe timings can be taken into account by an appropriate procedure [7]. Ideally estimat and Bills of Quantities should reflect this costing structure, matters discussed 'Design realisation' later in this chapter.

3-75 In addition to grouping information by activity, contractors must be able to identi resources (men, commodities and plant) by their performance, availability and co

3-76 Commodities are normally identified in contract documents, or sufficiently close specified for a suitable material to be selected. In either case the extension of da co-ordination to include the identification, specification, and the performance commodities would serve this need. Contractors' requirements would differ slight from those of designers in that a contractor would be more interested in source availability, transport, packaging, prices and discounts, matters that are discusse when the whole subject of a commodity catalogue is considered.

3-77 Contractors did not consider the categorisation of mechanical plant to be a burnir issue, presumably because planners and project and plant managers have an expe knowledge of the equipment on the market. Nevertheless, as plant becomes mo specialised, there seems to be considerable convenience in having a categor for plant which could act as a vehicle for information about the performanc availability and price of plant of different kinds.

Operations on site

3-78 The Station's interest in the information requirements for the daily management ar execution of building work, reaches back to 1953 when instructions were prepare to site supervisors and chargehands to erect prefabricated houses during a study alternative methods of house construction [17]. This interest was renewed during th study of operatives' skills when an attempt was made to analyse and record th technical content of different types of building operative's work, including the for of instructions [18]. No publishable material emerged from this part of the stud because of the fragmentary and elusive nature of instructions which are ofte highly informal, drawing heavily on an operative's prior experience. A similar attemp made during a survey of labour mobility on fifty sites concurrently with this study data co-ordination, also floundered. Hence this aspect of the present study is base primarily on the Station's considerable experience of observing work on buildin sites.

3-79 Site supervisors use information and the resources made available to discharg four functions each of which has a different requirement for information Th functions are:

- to determine the task next to be undertaken
- to ensure that resources required (including information) are available
- to instruct operatives
- to control progress and the quality of the finished work.

* See Glossary

3-80 The following assumes that supervisors will be provided with an adequate programme, supplemented by a schedule allocating resources to activities and perhaps by a projection of the overall use of resources and the expected cash flow. If this is not provided, site supervisors will have the additional task of devising a programme, possibly on a monthly basis, so that they can initiate and maintain overall control of progress. Only exceptionally should programmes be dispensed with, when a supervisor and his chargehands are exceptionally well-experienced in the type of construction to be undertaken (for example, firms specialising in low-rise dwelling construction), although even in these circumstances it is advantageous if supervisors use simple progress charts to monitor progress on site. However, for the purposes of this report, an adequate programme based on activities is assumed to exist.

To determine the task next to be undertaken

3-81 Many factors may make it convenient to further sub-divide activities into tasks, each representing that work to be done to create a work-piece (3-59 *et seq.*). These include:

Availability of operative labour

Availability of material

Positioning of temporary work e.g. scaffolding

Anticipating the redeployment of operatives to another gang before an activity can be completed

Other and more pressing demands for multi-purpose plant

Convenience, e.g. dividing an activity into tasks each of which can be completed between working breaks, or within working days

Absence of information

Overriding priorities—perhaps variations ordered by client.

3-82 All these factors, and many more, impinge on site supervisors who must constantly appraise the situation in order to redeploy the resources available in the most effective way. Hence the sub-division of activities into tasks is not a mechanical procedure, to be done at leisure, but a procedure that must be carried out in the heat of the moment. The ability to discharge this procedure properly distinguishes men from boys, and is an acquired skill learnt through much experience. Recently attempts have been made to devise rules[19] to make some of the decisions taken by site supervisors amenable to calculation, and games have been devised to reinforce teaching methods.

3-83 In order to discharge this difficult task site supervisors must have access, and immediate access, to a considerable volume of information. Some of this is operational, the progress intended and that achieved, the resources available, and the way that these are likely to change in the immediate future. But the rest relates to the project, and in order to be able to appraise the situation it is necessary that this information should be presented in a systematic way so that time is not spent in searching for information that does not exist, or in resolving difficulties created by inconsistent drawings, specifications, and bills of quantities.

3-84 Objections to the 'production information' now provided are numerous. It is often unsystematic so that site supervisors must learn to find their way about the relevant documents. Lack of co-ordination occurs within, as well as between projects, particularly when drawings are prepared by numerous specialist designers; rarely are attempts made adequately to cross-reference drawings, specifications, and bills of quantities and even when this is done the cross-referencing almost never extends through the work of several designers[9]. The result is inaccuracy and inconsistency, for example two services to be accommodated in the same space, perhaps crossing in the depth of a floor screed. Such errors cannot be entirely avoided by data co-ordination, but the existence of an adequate method of cross-referencing should make systematic checking and up-dating more feasible.

3-85 Designers do not always appreciate the design content of e.g. formwork, pipework, conduit and cabling etc., the execution of which is often left to chargehands and operatives. When operatives are expected to carry out work with a design content, it is essential that they are given information appropriate to designers. Such information would include the performance of the thing that is to be designed, together with the restraints imposed by the project, particularly by adjoining work.

To ensure that the resources required are available

3-86 Resources include cash; commodities; consumable and non-consumable materials; equipment and operatives. A projected cash flow, produced by any adequate accounting system, will be sufficient to discharge the first requirement. Availability of plant can be checked reasonably easily, although it would seem convenient if the industry had a system of categorising plant so that enquiries could be made about a class of plant, rather than about a particular maker's reference number. Checking the availability of commodities and materials will be facilitated if recommendations made earlier can be followed, namely that materials suppliers and manufacturers should include on despatch notes and invoices the activity number to which the materials relate, information that could be re-sorted on an activity basis and compared with the programme to show when action is needed to expedite delivery.

3-87 Problems associated with ensuring the availability of operative labour, already discussed, may be simplified if there is a closer matching of operatives' training and capabilities with the work to be undertaken.

To instruct operatives

3-88 It should be noted that great reliance is placed on the prior knowledge of operatives, and justly so for this is part of their expertise. Operatives, whether or not formally trained, acquire a deep insight into building methods and the way in which their work affects and is affected by others, e.g. the work of labourers and tradesmen is so integrated in bricklaying and plastering gangs that few verbal instructions are required either when setting-up or during work periods. Operatives also learn a great deal about a project, particularly in repetitive construction. This acquired knowledge about the extant work, its character, the construction method, the standards expected all supplement any instructions actually given to operatives. Therefore, in actual situations, very little of the information listed below is actually given. Observations on site have shown, however, that low productivity is almost always associated with new tasks and that complicated projects create high non-productive time because neither operatives nor their supervisors are able to solve the organisational problems before them. Therefore, in these circumstances at least, it is possible that more explicit information would increase productivity and thus pay for itself.

3-89 The outcome of any task is a work-piece. The main subjects about which information is required are the work-piece itself, the resources (labour, materials and plant), and the operational method including restraints placed upon the execution of tasks, e.g. the standard required, operational methods, payment for the work, sequence and access, and precautions to ensure safety.

3-90 The work-piece needs to be identified and located and the work to be done described often idiomatically.

Location is usually by reference to extant work, or to setting-out marks, and this presents little difficulty. More difficulty is encountered in indicating the standards of accuracy that are expected—there is no tradition—although this can be done by giving operatives jigs or spacing rods or the like. Quality is normally indicated by trade usage; when the standard required cannot be inferred the recognised practice is to provide sample pieces.

The boundaries of a task are often indicated by extant work, or by natural boundaries, so that quantities are indicated only when the character of the materials makes this necessary (sometimes cutting lists for carpenters) or to inform operatives about bonus targets.

Operatives need to be given the essential 'dos and don'ts' of their tasks together with any steps they are expected to take to fit in with the work of other operatives. Both are important, and neither can be inferred, hence this informa-

tion should be clearly stated in the production information and cross-referenced from the 'work-piece' heading in the Bills of Quantities.

3-91 Gangs need to be told about the resources allocated to work-pieces, especially when the project is non-repetitive or complicated. Observations on site show that high non-productive time is a feature of these projects, part of which is attributable to not having the commodities, equipment and materials available.

3-92 Finally, operatives also need to be given clear guidance about the way in which their tasks fit into the general operational pattern.

In order to preserve the identity of activities—the main carriers of information on site—operatives need to be told the activity number and the actual start time and duration, including targets.

For conventional operations, few instructions about working methods will be required. Unconventional tasks demand some elaboration, and time can be wasted and unacceptable work produced if proper instructions are not given—with an emphasis on instruction rather than mere direction. Failure to instruct operatives especially about such matters as structural systems or weatherproofing systems can contribute to costly and perhaps dangerous failures [20].

Instructions are needed about limitations on access and methods and times for handling materials, especially when cranes or hoists are to serve several gangs.

In view of the industry's poor safety record, better instructions are needed about the safety of operatives (use of safety helmets, harnesses, goggles), about the safety of plant (securing tower-cranes in windy weather), about safeguarding the materials and the work-piece (protection against frost), and finally about safeguarding the general public against risks and nuisances.

3-93 Given a stable labour force and repetitive construction only nominal instructions are required, and these conditions obtain in many sectors of the industry; for instance much of speculative and local authority house-building, or specialists' organisations undertaking, e.g. piling, structural work and chimney construction.

3-94 Much of the industry, however, is engaged in general contracting, employing a mobile labour force and tackling a wide variety of projects. In these circumstances it is possible that the effort entailed in giving more explicit instructions would be more than offset by the reduction in non-productive time (awaiting instructions) and in abortive work. A few contractors, general and specialist, are moving towards a work-card system which tends to follow the information pattern outlined in this report, *work-piece* and *activity*, sometimes supported by sketches. The task of preparing these work-cards can be viewed as part of the planning function. One contractor claims this has two advantages; it unearths inconsistencies and information requirements long before they are normally detected, and site supervisors freed from the chore of information hunting can devote their energies more effectly to instruction, supervision and control. Part of this information could be extracted from production information, part from national standards for technical solutions and construction techniques, and part from the contractor's programme and project file, all of which would feature in a system of data co-ordination categorised in an appropriate way. Data co-ordination viewed more broadly could make a significant contribution, by helping to ensure a good matching of education, training and retraining with the work that is to be expected of different occupational groups. Training methods, practical and theoretical, could be matched with the requirements of a national standard specification so that operatives became well versed in preferred methods of working, in the knowledge that these methods were likely to be encountered on the majority of buildings.

To control progress and quality

3-95 Quality control gives rise to much friction, largely because of differences in interpreting 'trade usage'. Data co-ordination *per se* will not improve matters until a more formal approach to education, training and trade testing leads to more uniform standards reflected in standard specifications.

3-96 Progress recording will present few practical difficulties, and the task will be reduce if work on site has been able broadly to follow the pattern of activities indicated in th programme. Progress control is more difficult, but it will be facilitated if adequat resource schedules have been prepared and these and the construction programm regularly updated, matters made more possible by data co-ordination.

Design realisation

3-97 All that lies between design and construction has been designated design realisatio Commencing when design has resulted in the choice of the principal structura techniques and commodities, and being completed at the commencement c planning for construction on site, design realisation is concerned with the fina selection of products, with the preparation of production information, and wit estimating. The outcome of design realisation, a description of the project in greate or lesser detail and an estimate of the cost, should be so arranged that constructor can use the information directly, without further re-measurement or re-allocatio any necessary re-arrangement being a simple mechanical process. Moreover som of the information produced during construction about progress, buildability, cost or performance recorded during acceptance tests forms feedback to designers whos information needs must be kept in mind.

Input to design realisation

3-98 At the completion of detailed design the information available will normally be description of the project, conveyed by the brief, drawings in greater or lesser detai schedules of one kind and another and a cost plan, together with specificatio notes.

3-99 Although the brief is one of the factors dominating the design stages, it does no make a direct contribution to design realisation, except when briefs include sub stantially complete statements of the constraints dictated by the site and by adjacer buildings. These should be written into production information so that they may b taken into account during estimating and planning and so that site staff may b properly instructed. When briefs are deficient in this respect, data must be obtaine from the site survey, or sought separately.

3-100 Drawings are by far the most important vehicles of data for design realisation. If th project has been co-ordinated it is possible that the drawings furnished by th main and specialist designers will fall into a recognisable pattern, and be to commo scales, and be compatible. This, the Station is led to believe, is unusual so that on function that falls to design realisation by default is to introduce order into th arrangement of drawings. When specialist designers have prepared drawings, rathe than working from master-prints provided by the main designer, these should b checked to ensure that the assumptions made by each specialist are mutuall consistent.

3-101 The cost plan should have been updated during the detailed design stage and b complete with an outline specification, the latter providing an independent chec on the drawings and the outline specification.

3-102 Finally, the information available at the commencement of design realisation may b in the form of schedules of rooms, fittings, finishes, or components. Most of th contractors and specialist designers visited during the course of the study were c the view that schedules were a useful way of collecting information together; the could be improved but were already widely used, for example, for:

Verifying compliance with clients' requirements (especially for large projects

Keeping track of design decisions

Avoiding proliferation of types, e.g. of doors, basins, finishings in large building

Preparing data for take-off of quantities and materials

Ordering, checking delivery and instructing operatives.

They thus have a usefulness running through the whole building process.

3-103 Applying computers to schedules would enable room, finishing or fitting schedules to be produced at will and a wide range of questions to be answered, e.g.

What is in this room?

How many items of A have been specified and when?

Has any product of type B with characteristics C-D-E been specified?

Has the client's requirement that every space F should have a G been met?

Is space H on wall J in room K vacant? (This assumes a room plan, with the development of walls).

Functions of design realisation

3-104 Design realisation fulfills three functions: firstly, to select or finally specify all the commodities to be embodied in the project; secondly, to prepare production information; and, thirdly, to prepare estimates.

To select or specify

3-105 Commodities may be uniquely identified (i.e. use 'this' product), or indicated by a detailed specification or by a performance specification, each successive method providing the contractor with a greater range of choice. Identification* solves many problems of communication because an identity number, qualified if necessary, would be sufficient to lead contractors to the relevant catalogue, to an abbreviated commodity file, or to a central commodity file, if one existed. The second method requires sufficient specification to ensure that contractors can select commodities to satisfy the designers. At present specifications for similar things vary from one project to the next, and from one organisation to another; some standardisation would be valuable.

3-106 Standard specifications are regularly employed by some private practitioners and by large client organisations, the Greater London Council and the Ministry of Public Building and Works in particular. Experience has shown that these specifications can materially reduce the effort and time taken to produce specifications for a wide variety of building types, experience that is confirmed by the widespread employment of standard specifications in Scandinavia. The issue of the feasibility of preparing a national standard specification rests with a Committee working under the aegis of NEDO and with the full-time support of John Carter. A related subject, the role to be played by standard details, is being investigated by Gareth Slater, who holds a Building Centre Trust Fellowship at the Building Research Station.

3-107 The report of this Committee recommends that a national standard specification should be prepared, along fairly conventional lines with the items grouped in trade sections corresponding to the Standard Method of Measurement for Building Works, and that means should be provided to amend the specification in the light of usage, and to develop alternative arrangements and formats. This can provide one of the starting points for data co-ordination.

3-108 The third alternative, to use performance specifications, suffers from the disadvantage that performance specifications are lengthy, because every relevant aspect of performance must be quantified and methods of test prescribed. These performance specifications cannot be widely used in project documentation unless there is available an agreed standard to which reference can be made.

3-109 These three methods in any case boil down ultimately to the identification of commodities or standards, except for 'specials' which must be described by a drawing, in detail if accompanied by a descriptive specification, or in outline if accompanied by a performance specification.

To prepare production information

3-110 Planners need sufficient information to appreciate the scope of a project, to select a feasible construction method, to identify the activities in order to prepare a construction programme, to assess risks and constraints in order to estimate productivity, to

*See glossary

prepare resource schedules, to prepare a budget and cash flow prediction, and confirm the profitability estimated at tender stage.

3-111 Appreciation of projects can be obtained only by an extended visit to sites, elaborate in site reports, and by a thorough perusal of drawings and specifications. Drawing are used to identify location, to gain an impression of the project as a whole and th circumstances surrounding the construction of work-pieces, and to verify that th constructional method and type of equipment selected are feasible. At the stage o outline planning, interest centres on the general arrangement drawings, possib supplemented by more detailed information for critical issues—perhaps, for exampl to determine whether formwork can be re-used. Later, however, more detaile consideration will have to be given to the method, the materials and the equipmer and reference will be made to drawings to a scale larger than that normally used f general arrangement drawings (1:100).

3-112 Planning and control centres around activities—the creation of work-pieces—a already described, and information in bills of quantities should be grouped accor ingly[1, 21, 22, 23, 24, 25].

3-113 On the arguments already advanced for project costing greater attention should b paid to the bill dealing with preliminaries since it is assumed that contractors w wish to price these separately and realistically, because this will be in their intere if a distinction is to be made between time-dependent costs and the remainder. C the same argument, a distinction should be made between the materials and no materials element of each price, an innovation that would have two advantage Firstly, it would allow estimators to price the non-materials element (the contracto contribution) whilst awaiting quotations from suppliers—and the Station is led believe that these quotations often arrive at the last moment and seriously delay th preparation of estimates; secondly, this separation would make simpler both interi valuations and the calculation of cash flow.

3-114 On site information is required:

To obtain a general impression of the project and the problems it present particularly features that dictate a sequence of construction. This function fulfilled by general arrangement drawings, the larger the scale the better.

To check the reliability of the information provided, in particular when th work of more than one trade is juxtaposed. It is for this purpose that si staff would find schedules useful. Also general arrangement drawings a often supplemented by additional sketches or overlays in order to chec clearances, and to detail temporary work.

To set-out. Except for the smallest projects, setting-out drawings for the maj parts of the building at least, would facilitate setting-out and checking, the latt being a necessary procedure in view of the vulnerability of profiles and th mistakes made in dimensioning general arrangement and detailed drawings.

To instruct operatives. Although operatives require relatively little informatio and much of this can be obtained from the description of work-pieces and fro schedules, setting-out information must be obtained from drawings. From th standpoint many drawings are deficient in that insufficient care is paid jointing problems, and to the relationship between finishings, fixtures, fittin and services, possibly because these features do not appear as important issu on small scale drawings and because drawings assume standards of accura unobtainable on site. Dimensions should be referenced to those parts of th project that will exist when a work-piece is to be constructed and draughtsm should remember that elaboration of the detail within components provides n additional information to site supervisors and only clutters drawings.

3-115 Planners and site supervisors all emphasised the benefits that would flow from goo cross-referencing between drawings and Bills of Quantities (assuming that specif cations are embodied in Bills of Quantities or are related closely to them). If contra tors are primarily interested in work-pieces at locations, it would seem these shou

provide the key for cross-referencing. Finally, given the use of computers, Bills of Quantities could be completed by a list of materials either uniquely identified or specified and arranged to suit the usual organisation of materials suppliers.

Estimating

3-116 Procedures for estimating are spelt out in some detail in the Institute of Building's handbook, 'A Guide to Good Estimating Practice'[26] which illustrates the essential dichotomy between existing procedures and the structure of the information estimators now receive. The measures proposed as a result of this study of coding and data co-ordination should improve this position, notably by making estimators more aware of site results.

3-117 Having decided to tender, the first task is to extract a list of provisional and pc sums, together with the bulk quantities of the items the main contractor expects to undertake, to indicate the demands that will be made upon the main contractor's resources and the extent to which the contract will be under his control. The next step is to extract lists of materials from the Bills of Quantities so that quotations may be obtained from suppliers and to extract from the Bills of Quantities and specification, data for those trades the main contractor proposes to sub-contract and for items that are to be manufactured, e.g. joinery. These time-consuming (and possibly error-producing) tasks in no way contribute to the actual estimate, and only reflect the inadequacy of the production information estimators receive.

3-118 The next task is to extract from the Bills of Quantities, perhaps with the assistance of the general arrangement drawings if available, sufficient information to prepare an outline construction programme, e.g. overall quantities for excavation, structure, and the work to be done by the principal finishing trades, together with an estimate of the time likely to be taken by the specialist sub-contractors, some of whom may not have been appointed. Having completed this task and a site survey, the estimator can now commence the task proper, i.e. to select an appropriate construction method, to estimate the gang strengths required and the tempo of work on site. From these data, an outline construction programme can be prepared to indicate the feasibility of the solutions selected and the likely incidence of overhead, on-costs and major equipment costs. It will be noted the first step in this procedure is to extract and translate data to another form.

3-119 Finally, estimators, having received quotations and obtained an all-in rate for labour, proceed to price the bill, estimating the effect of complexity on productivity, from data in Bills of Quantities and from an inspection of the drawings. This involves, for each of many hundred measured items, a separate calculation of the cost of commodities, productivity, and an allowance for equipment and plant, information that may remain in an estimator's file and is not made available either to project planners or to site supervisors. The situation is also made more difficult because information about productivity cannot be fed back in terms of the aggregated quantities given in Bills of Quantities, because all that can be observed on site is the completion of workpieces, i.e. activities. Hence estimators do not always have data available in a form that is compatible with Bills of Quantities, and a large measure of subjective judgement intervenes.

3-120 Data co-ordination could help to eliminate the non-productive elements of estimating, because information would be arranged so that lists of materials were ready to be extracted, and information would be grouped so that activities could be selected to prepare an outline construction programme. Moreover, since estimates, programmes, site control, and the Bills of Quantities would be structured in the same way and would state measurements compatible with site recording, in due course feedback would be more feasible and estimators would have to hand reliable productivity data.

3-121 The specialist report, 'Contractors' management' assumes that production information is arranged so that contractors' estimators can readily identify the main operations and thus derive estimates from outline construction programmes. Subsequently, during planning, these outline programmes would be further developed using more detailed information to produce a construction programme also based on the execu-

tion of work-pieces, that is on activities, when resources are allocated. The way tha this information can be used during project control, progressing and costing has bee described, hence information fed back to management for project evaluation will b compatible with the initial estimate. On the basis of these assumptions three suites c procedures have been prepared, the first dealing with *selection* (the selection c projects, appraisal of alternative working methods, outline planning and cost est mating, and appraisal of tenders), the second with *planning* (detailed planning multiple project scheduling, personnel selection and bonus targeting), the thir with *control* (progress reporting and cost control, materials utilisation and costing These are not further considered in the main report because they make no demanc for information required for or produced by other functions other than that require for project planning and control.

3-122 The object of the whole of the building process is in fact to satisfy a client's needs b the construction of a building and there are strong arguments for the informatio needs of the contractor to be predominant throughout the process, because th would also produce information needed by the other participants. The steps propose in this report would help in this respect.

Materials suppliers and manufacturers

3-123 During the study attention has been paid to the transactions between those engage in building processes and materials suppliers and manufacturers, views bein obtained both from members of the building industry, and from materials supplie and manufacturers. Fortunately this study coincided with two other studies; ' feasibility study into computer services for builders' and plumbers' merchants' b the National Computing Centre on behalf of the National Federation of Builder and Plumbers' Merchants[27] and 'A study of commodity coding' by CEIR Limitec for the National Computing Centre[28]. Both were published before the preser report was drafted. Contact had been maintained between the team and thos responsible for the reports, and it was known that the broad conclusions of the thre studies were compatible. Acknowledgement is made to the National Computin Centre and CEIR.

3-124 This section considers the problem of transactions between those engaged in th building process and materials suppliers and manufacturers from the standpoint c each, before drawing the three themes together.

From the standpoint of the building process

3-125 From the standpoint of those engaged in the building process, merchants and manu facturers fulfil much the same rôle, as is the case when specialised products a ordered from and delivered by manufacturers. Therefore, at the risk of infuriating th parties concerned, no distinction will be made between them. Participants in th building process require:

To be made aware of the available commodities

To be provided with technical information about them

To deal expeditiously and efficiently with commercial transactions.

To be made aware of available commodities

3-126 This naturally involves a complete range of sales literature from eye-catchin advertisements to full descriptions of individual products, their properties, an specification. Too often the information available is of a very general character an much will be gained if agreement is reached as to the characteristics that should b mentioned for different classes of commodities, characteristics that should b chosen to reflect the interest of designers and constructors at different stages of th building process, and be cross-referenced to indicate associated literature, standard and Codes of Practice. From a purely practical standpoint, standardisation of siz method of binding and of methods of filing will be to the advantage of everyone i the industry, and the CIB Master List of Properties[29] is helpful in suggesting conten

* Now called Scientific Control Systems Ltd. (July 1968)

3-127 Manufacturers' and suppliers' representatives play a positive rôle in the construction industry. Although a comprehensive system of data co-ordination would seem to make them less necessary, it was the opinion of the majority of manufacturers and merchants that representatives would continue to be required, perhaps on an increasing scale, in order to ensure that their products were brought before their customers and that a proper service was provided.

To be provided with technical information

3-128 Technical information has been partly considered in the paragraph above. It would seem, additionally, that effort is justified in order to couple technical information with each of the three stages of interest of a designer in a project, expressed by the following questions:

Do solutions exist . . . ? (sketch stage)

Which of the possible solutions is preferred . . . ? (scheme stage)

How can the selected product be embodied in the project . . . ? (production information)

3-129 Similarly, contractors' interests can be expressed by answers to the following:

Does *this* product satisfy the specification?

Are there cheaper alternatives?

Are there constraints on workmanship?

Are there special acceptance tests?

Is this product available?

Are there any benefits that vary with the source of supply?

Clearly one document that set out to answer all these questions would be bulky and expensive to produce, and no single user would need all the information that would be included. It is possible, therefore, that a more co-ordinated approach to the provision of information could result in more useful information at less cost to manufacturers.

To deal expeditiously and efficiently with commercial transactions

3-130 There are four commercial transactions; submitting quotations, receiving orders, delivering products, and rendering accounts. Expedition and certainty are vital so that quotations are quick and materials delivered on time. Contractors, or others, must furnish merchants or manufacturers with a statement of their requirements which is normally couched in plain language (sometimes overridden by trade terms) or by references to a catalogue which may, or may not, be up-to-date. In either case ambiguities may arise, causing errors or delay. The information returned to the contractor is usually a list which then has to be re-allocated in estimating and project costing. Earlier, a suggestion was made that contractors should include with their enquiries the appropriate activity number and date for delivery, which would then be associated with the materials as delivered, by the delivery note and the invoice.

3-131 At present few merchants or manufacturers price delivery notes; they send invoices later—often much later—than the goods. This practice is disadvantageous to contractors who have to adapt costing systems to take account of the time-lags between the delivery of materials on site, their incorporation in work, certification and honouring of the certificate, receipt of the priced invoice, receipt of the statement, and payment. Some of these difficulties would be resolved if the accounting system used by merchants and manufacturers enabled invoices to be sent at the same time as goods, or within some mutually agreed accounting period.

3-132 Improved credit control would stem from better management information being available to suppliers.

From the standpoint of merchants

3-133 The problem, as seen by the merchants, is fully discussed in 'A Feasibility Study int Computer Services for Builders' and Plumbers' Merchants', to which referenc should be made[27]. In this the authors distinguished two main areas in whic computer usage and data co-ordination could be expected to effect an improvemen to provide management information, and to reduce or eliminate clerical costs.

3-134 Improved management information could lead to:

Improved effectiveness of investment and stock control

Improved profitability, by providing profit breakdown, sales analyses, custome and product performance

Tighter credit control as and when this is considered to be necessary.

Not all these matters are of direct concern to those engaged in the building proces and will not be further considered.

3-135 The reduction in clerical costs would entail pricing quotations, handling order pricing delivery notes and invoices and accounts all by computer. In turn this woul require a system of commodity coding. Major firms could devise their own systems or a national system could be developed; this is discussed in the concluding part c this chapter.

3-136 The authors of the NFBPM report recommended that the merchants should start b implementing better management information, rather than by improving the trans actions in the industry. However, computerisation of the latter is of more interest t the building team and should make it possible to release or to deploy on other wor a large number of merchants' clerical staff now required to price quotations an invoices, a task that needs constant reference to price data, to discount lists, and t customers' credit ratings. Since such tasks do not appear to involve judgement, should be possible to computerise them entirely, and thus provide the contractin industry with a faster accounting service. Therefore it is argued that the contractin industry should be prepared to make concessions in order to bring this about.

From the standpoint of manufacturers

3-137 Manufacturers, when acting as merchants, will have to face much the same problem and will be open to gain the same advantages from better management information and from better and faster transactions with their customers.

3-138 Manufacturers, more than merchants, are concerned with problems of marketin and therefore with the general structuring of information to their customers, a subject discussed above.

3-139 Manufacturers also need to generate information about a pattern of demand i order to balance the work-load in different production areas. The Station was tol that few manufacturers receive an adequate warning of demand, even for majo orders. Therefore production planning and control has to be highly adaptable i order to respond. Manufacturers, therefore, would benefit from any procedure that could be introduced to give them an early warning of demand, and it is possibl that this could be achieved by offering a price advantage or a guaranteed delivery i response to early ordering.

3-140 One manufacturer and major client at least have started to integrate their require ments for information. The Hertfordshire County Council and the Critall Manufac turing Company Limited[30] realised that the types of windows specified and thei arrangement gave all the information necessary to determine production runs, inter mediate storage, transport, estimates, glass sizes, areas for painting, ventilation rates etc. The organisations concerned prepared a procedure whereby a sketch elevatio indicating the layout of window types was accepted by the manufacturer and use to generate all the information listed above. Such circumstances must arise wit other components, precast concrete units for example, and the way would seem oper

for further developments along these lines providing the conventions to be followed are acceptable to all the parties concerned, a situation that is likely to happen most readily when an integrated design office has a continuing programme of work that creates a continuing relationship with a manufacturer or manufacturers. Once developed, such systems could be made open to other users, as part of the service offered by manufacturers to attract customers.

From the standpoint of data co-ordination

3-141 Each of the groups discussed, designers, constructors, materials suppliers, and manufacturers, maintain commodity records of one kind and another. By commodity records is meant all literature prepared by manufacturers, factors, materials suppliers and merchants, which list commodities together with their properties in greater or lesser detail. At present such records are most invariably written; in future it would be possible to retain them on computer data files, whether these are central files or files maintained by individual organisations. Taken together these records include *all* the information needed to be associated with each commodity, whether for internal purposes or for external communication. Many of these records duplicate each other and the CEIR report showed that departments of large organisations duplicate many records. Therefore such organisations, at least, would gain by having a central commodity file listing all the attributes of interest to the organisation as a whole, and it is almost certain that such a record is an essential prerequisite to the integration of the different departments that is made possible by computer application. A similar argument can be advanced from the standpoint of the whole building process, designers and constructors have a continuing requirement for information about materials, products, components—the things from which projects are made—which could be held on a central commodity file.

3-142 Hence the case for a comprehensive commodity record for the building industry, because all relevant pieces of information are, at one time or another, required. But the very dispersion of the material makes data retrieval difficult, and regular updating impossible. These disadvantages would be avoided if a central record could be prepared, but the cost of this would be considerable and it is therefore necessary to consider just what would be entailed; this is done in Chapter 8.

3-143 It must be emphasized that this central commodity file could be organised in several ways. The simplest arrangement would be for the product information to be prepared by individual organisations as at present, but with prior agreement as to the form and content of the information. Alternatively, such information could be collected together in a file presenting a class of commodities, and hence one element of a central commodity file. The whole file could grow in scope as agreement is reached on the form and presentation of product information. Subsequently this information could be held in computer data banks, whether these are owned by individual organisations, or are merged into a central data bank. Frequent references to 'a central commodity record or file' refer to all these concepts.

3-144 The properties of interest to the building team have been discussed throughout the present and preceding chapters, and are drawn together in Table 1. In practice, the degree of detail required will change from project to project, and the interest shifts as the project proceeds. The table does not set out to give the contents of a commodity file, although obviously it is suggestive in this context.

Table 1

Information about materials and products

showing shift of interest as jobs progress

		CD ASSESS	E DESIGN	E DETAIL	F SPECIFY	G MEASURE	H ESTIMATE	J ORDER	– PRODUCE	– TRANSPORT	K STORE	K INCORPORATE	K INVOICE	L OPERATE
1 Identification	**Generic:** description sufficient to indicate type of product and its use; classification symbol	●	●											
	Specific: information to identify the product without ambiguity (e.g. NATO stock number); it will signify size, colour, material, etc. and will include name of manufacturer, trade name or brand, manufacturer's own reference number, etc. as appropriate.		●	●	●	●	●	●	●	●	●	●	●	●
2 Properties	Indication of performance	●												
	Indication of composition/structure	●												
	References to finished constructions—completed projects from which the performance of the product may be appraised	●												
	Appearance, including finish	●	●	●		●								
	Properties of building element in which product is incorporated	●	●	●										
	Detailed composition/structure		●	●										
	Physical, chemical and biological properties		●	●										●
	Durability (related to maintenance, if appropriate)		●	●										
	Performance details		●	●										
3 Dimensions and measurements	Range of nominal sizes (e.g. window 4 ft. 0 in. wide x 3 ft. 0 in. high, etc.)		●	●		●	●							
	Actual dimensions, including tolerances (e.g. window 4 ft. $11\frac{13}{16}$ in. x 2 ft. $11\frac{13}{16}$ in. etc.)			●		●	●		●					
	Rules for measurement (SMM, trade custom, etc.)					●	●							
	Net quantity in completed project					●	●							
4 Costs and accounting	Gross quantity						●	●	●	●	●			
	Approximate cost as fixed	●	●											
	Running costs	●	●											●
	Prices, including accessories and fixings		●				●	●					●	
	Delivery costs/charges		●				●	●		●				
	Discount—customer		●				●	●					●	
	—quantity		●				●	●					●	
	—settlement						●	●					●	
5 Application (general)	Range of accessories	●												
	Methods of fixing/placing/erection	●												
	Details of accessories			●										
	Details of fixing/placing/erection			●										
	Initial finishing treatments			●										
	Architectural and constructional details including associated details, junctions with other work, etc.			●										
	Working characteristics, use of special tools, etc.				●	●	●				●			
	Materials constants, i.e. gross quantity per measurement unit of finished work						●							
	Labour constants						●							

Information about materials and products

(continued)

		CD ASSESS	E DESIGN	E DETAIL	F SPECIFY	G MEASURE	H ESTIMATE	J ORDER	– PRODUCE	– TRANSPORT	K STORE	K INCORPORATE	K INVOICE	L OPERATE	L MAINTAIN
Application (project)	Where to be used—precise location in project	●	●	●	●	●	●				●	●			
	Selected fixing method			●	●	●	●					●			
	Selected finishing treatment			●	●	●	●					●			
	Assembly (prior to installation) instructions						●					●			
	Protection of finished work				●	●	●					●			
Availability	Regional limitations	●	●												
	General statement on availability—time		●												
	Current state of availability						●	●							
	Critical dates (phased if necessary)—delivery							●		●	●				
	—despatch								●	●					
Distribution	Method of transport (for packaging)								●	●	●				
	Gross sizes and weights of packages						●		●	●	●				
	Destination (site address)							●		●					
	Access to site (including unloading restrictions)					●	●	●		●	●				
	Unloading facilities required at site					●	●			●	●				
	Handling characteristics				●	●	●		●	●	●	●			
	Storage requirements, including protection				●	●	●		●	●	●				
	Return of packing materials						●		●		●		●		
Testing and operation	Tests				●	●	●	●	●			●		●	
	Operating instructions													●	
	Routine cleaning and maintenance schedule													●	●
	Periodical maintenance/overhaul													●	●
	Guarantee		●						●					●	●
	Replacement—ease of replacement and availability of spares		●												●

In addition to the above, a supply organisation will require the following information for its own internal processes such as stock control, sales analysis, etc:

Own catalogue number, part number, or other brief identification (e.g. a 'short code' linked to the full code of 1 above)

Commodity group

Customer information:
- identity
- credit limit
- discount class
- sales area

Stock location (depot, warehouse, floor, bin . . . . .)

External source (manufacturer or other supplier)

Stock levels:
- maximum
- minimum (=re-ordering level)
- rate of turnover, past
- rate of turnover, predicted future
- economic ordering lots
- availability (=delivery time from external source)

Chapter 4

The purposes of an information system for the building process

4-1 This chapter commences by crystallising the major conclusions of the field studie and then goes on to consider what these mean in terms of an information systen This statement is matched to the building process by repeating, in tabular form i Table 2, the arguments spelt out in the previous chapter, thus relating various aspec of data co-ordination to building processes, as exemplified by the RIBA Plan c Work, with the proviso that this does not necessarily imply any particular tim sequence.

4-2 The general picture derived from the previous chapter is not one of lots of types c information whizzing between participants, but of a few basic types of informatio of interest to all, and of a major need to consult previous experience (mostly dat about projects) and other non-project information.

4-3 The first major type of information at the design stage is the client's brief—th statement on which, when fully developed, the whole design rests if it clearly define the client's requirements by stating the performance expected of the project, and th restraints on the freedom of designers (planning constraints, features important t the client, costs, timing).

4-4 The second major type of information passing between most participants is the forr the building or its parts will take. They need to know shape, dimensions, sections room sizes and so on. This information starts in a tentative and imprecise form that i progressively made more precise throughout the design stage. All these participant need to know the latest state of the information as the design proceeds; desig optimisation would be greatly helped if this were possible.

4-5 The third type of information is related to resources, human, commodities, materials products, components and plant. All participants need to identify (that is attac a label to) and specify (that is, describe in full detail) resources and to assur themselves that the performance of the resources selected matches the requirements

4-6 Apart from these types of information that are of major importance, most participant in the design process are working within certain general constraints (planning conditions, building regulations, working rules, statutory requirements, etc.) and ar making considerable use of past experience and past jobs. There is a major require ment for easy retrieval of relevant past work, of constraints imposed by regulation and the like, and of the results of research in a form that is related to the stage reache in the project.

What an information system must do

4-7 The rôles that an adequate information system must fulfil are now spelt out. They arise directly from Chapter 3 and effectively provide the first section of the criteria for such a system. Such a system must provide the means:

To classify information in categories that users need

To identify resources, i.e. to put a label on them, so that the flow of information does not have to be encumbered with long and significant descriptions and class indicators

To describe resources used in construction, giving comprehensive data of direct interest to all participants

To describe projects and construction tasks especially geometric form and the positioning of commodities

To foster the development of procedures by agreed conventions and a preferred vocabulary

To support information flow and achieve economy, rôles that pervade the others, and include the multiple use of data and standard details, specifications, etc.

4-8 Table 2 gives the outcome of the field studies in considerable detail. The rôles distinguished in the table are now discussed in order to obtain more extended definitions. It will be noted that rôles overlap and complement each other.

To classify information

4-9 Any system of data co-ordination must be able to classify information to facilitate its retrieval. There are many different kinds of information, including that relating to performance and requirements (e.g. regulations, codes, standards), information from manufacturers, and feedback information. Feedback may take two forms, either within one project for control purposes or between projects for the improvement of future working, the former giving the term its proper usage.

4-10 Performance is predicted during design and production; for example during design, predictions are made about the performance of systems, the cost of systems and building elements, and progress, and in construction about productivity, sequencing and costs. Feedback is a monitoring action, comparing performance data obtained during construction with predicted performance, so that corrective action may be taken if the departure between the observations and predictions exceeds prescribed limits. Feedback leads to improved performances and should be an integral part of every project.

4-11 Feedback between projects plays the same rôle with regard to organisations rather than projects, organisations being concerned with a succession of projects rather than with single projects. Performance is monitored in much the same way either to enable management to take corrective action to improve the functioning of the organisation as a whole, e.g. seek more work, or to improve the quality of the background information available to all similar projects e.g. standard details, cost data, productivity records.

4-12 Part of the purpose of the classification categories is to allow relationships to be built up between relevant groups of pieces of information e.g.

functional requirements/ /performance of systems/ /prices
functional systems/ /prices/ /running costs
building types/ /prices
building elements/ /technical solutions/ /performance/ /prices/ /running costs
technical solutions/ /experience
construction method/ /work element/ /operative occupations/ /
building element x location/ /recorded productivity
equipment characteristics/ /output/ /recorded costs

This list is, of course, by no means exhaustive.

4-13 Another purpose is to relate statutory and advisory information (building regulations, fire, safety and planning regulations; Codes of Practice; Agrément Certificates; British Standards) to building types, functional spaces and systems, building elements and construction methods.

4-14 A further purpose is to facilitate the compilation of schedules of resources with respect to building type, functional space and system, building element, technical solution, construction method. This would help in the compilation of the room schedules mentioned earlier in the report.

4-15 Hence the rôle *to classify information* may be restated as:
To provide sufficient categories for data to be classified and retrieved in order to

search through data about building types, functional spaces and syster technical solutions, building elements, construction methods, resourc (commodities, materials, occupational groups, equipment)

select functional system, technical solution, arrangement, construction meth and resources with regard to performance, specification, availability a cost

check compliance with constraints and with regulations

support feedback within and between projects.

To identify and describe resources

4-16 Transactions between participants often concern resources—human resourc plant and equipment, and commodities. When the transaction is a request for inf mation or a quotation, or an order, or an invoice, the resource may be identified specified. Transactions about identified resources need the minimum information identify the resource, because the recipient can attach to the identity other informati necessary for his own purposes.

4-17 Description of resources about commodities, plant and equipment needs informati (detail being dictated by circumstances) about such things as composition, properti (or performance), shape, dimensions, weight, application, distribution, and pric etc. For human resources, the information will be about occupations, productiv rates of pay, etc. Comprehensive information like this can serve many users includi project teams, materials suppliers, manufacturers, research organisations, cent government; within the context of projects the principal uses are:

to select resources with regard to performance, specification, source, availabil price

to ensure that the selected resources are compatible

to provide management information about e.g. stockholding, re-orderi labour requirements

to identify alternative resources

by identifying alternatives, to lead to variety reduction

to select occupational groups on the basis of technical solutions and constru tion methods

to select equipment with the required performance

to check the availability of all resources at the commencement of operatio and tasks

to record resource consumption with respect to work-pieces and tasks.

4-18 Hence the rôle *to identify and describe resources* may be restated as:

to identify uniquely commodities (the materials, products and componen embodied in construction, contractors' materials, consumable stores), equ ment (plant and tools) and occupational groups, in a way that will be convenie for the industry's transactions

to provide the means by which unique identifications can be assigned commodities etc. This should not involve long delays whilst identifiers allocated and should be cheap to administer.

to produce comprehensive central commodity, contractors' materials, co sumable stores and equipment files. This would require appropriate classifi tion, agreed sets of properties for each commodity and resource, and a prefer vocabulary, and the means to achieve them.

To describe projects

4-19 Without doubt, an adequate description of projects is seen as the most important feature of any system of data co-ordination. Also, all the practitioners interviewed wished to be told as much as possible about the form of projects, and to be informed immediately further data were added, or changes made. Hence any system must make provision to describe form, at least in the long term. Projects are described graphically and in writing, methods that will be considered separately.

4-20 Graphic description may be by drawings which are discussed together with other vehicles in Chapter 5. Any considerable extension of computer usage will require the form of the building to be described geometrically, since this opens the way to manipulations that cannot be achieved with facsimile reproduction. Hence any system of data co-ordination and coding must make provision for handling data describing form, and one method of doing so is outlined later in the report.

4-21 Given this facility, the way would be open to obtain perspective and exploded drawings at a reasonable cost and to determine, by simulation, problems arising during the outline and sketch stages of design, e.g. the most economical method of accomplishing large earthworks, the effect of layout on earthworks and on connections (roads, paths, sewers, etc.), the effect of layout on the 'quantity' of the building elements and, hence, on heat losses, costs, etc.

4-22 Written descriptions include schedules, specifications, and bills of quantities, all of which are discussed in Chapter 5. Each contains material that can be arranged by the classifications previously listed, to suit the need of different users, and the various arrangements have been discussed in Chapter 3.

4-23 From the standpoint of constructors, project information is improved if, where appropriate, it can be related to locations and to work-pieces, and a convention for location is needed.

4-24 Description of projects also includes operational methods, given prior to construction by estimates, project proposals, construction programmes, resource schedules, and during construction by progress reports, amended programmes and resource schedules and costing.

4-25 Hence the rôle *to describe projects* may be restated as:

to describe form by co-ordinates or other methods

to describe the technical solutions by describing work-pieces, identifying or specifying commodities comprising work-pieces, indicating the circumstances in which the work-piece will be completed, locating work-pieces within projects, and stating restraints to be observed

to describe operational methods by identifying the construction method, defining activities, specifying the resources to be employed, depicting the sequencing and timing of resources, resource scheduling, and progress reports and costing.

To foster the development of procedures

4-26 Procedures, it will be recalled, are sets of data operated on by routines. Hence the development and execution of procedures can be assisted by making data more accessible, by standardising the presentation of data, and by agreed methods of working.

4-27 Data accessibility should be improved by better classification, by documents arranged in ways convenient to users, by the existence of a comprehensive commodity file, by agreed methods of presenting manufacturers' information and by better communications. It will be noted that only the first two of these involve data co-ordination *per se*, the third would entail a major effort to bring together information already existing in many places, and the fourth would need improved arrangements within the building team.

4-28 Each procedure or set of related procedures is likely to require a different presentati of data and methods of working, and these need agreed conventions. The need f conventions for structural engineering has been anticipated by the Institution Structural Engineers and others must be derived to match the needs of procedur for analysis of environmental systems, waste systems, measurement, plannin progress control and costing, etc.

4-29 One of the ways in which these conventions can be made compatible is by the u of a preferred vocabulary. The need for a vocabulary also arises in the context commodity and work-piece descriptions, and it is likely that the terms selected cou serve these several purposes.

4-30 Hence the rôle *to foster the development of procedures* may be restated as:

to provide categories necessary for data retrieval in ways to suit the needs various users

to enable documents (drawings, schedules, specifications, bills of quantitie programmes, project proposals, resource schedules) to be arranged in wa convenient to users

to provide the means of co-ordinating conventions evolved for speciali procedures or groups of procedures, a task that includes the developme revision and extension of a preferred vocabulary

to provide the means to prepare suites of related procedures.

To support information flow

4-31 This rôle underlies the foregoing, and will be substantially discharged if the rôl outlined so far are fulfilled. There nevertheless remain two aspects, co-ordinati information flow, and creating circumstances leading to good information flow.

4-32 Measures necessary to co-ordinate information flow, seen readily by glancing columns 2 and 10 of Table 2, include programmes to state and monitor informatic flow, cross-referencing, up-dating information, avoiding the regeneration information.

4-33 Programmes, however constructed, are concerned with activities or events in desig or construction. Both demand and generate information, hence organisation programmes should be complemented by information programmes. This will b made more feasible if procedures define explicitly their information requirement and the form the data should take in order to suit the routines associated with th procedures. Better co-ordination would reduce the volume of information, because the use of standard details and specifications, and this would facilitate the manag ment of information flow.

4-34 Constructors, in particular, complained that documents were inadequately cros referenced, and that much information was repeated (perhaps inconsistently) several places. Two remedies are indicated: first, to have systems of cross-referencir based on classifications of interest to recipients (not to sources); second, to establis the type of information appropriate to each document: both are interdependent- inadequate cross-referencing is tolerable only when information is duplicated.

4-35 All participants—designers, suppliers, constructors—were anxious to be told changes in, or additions to, design, and of changes in the sequencing and timing activities. In part this requirement could be overcome by effective informatic management, in part it requires improved communications, such as terminals linke to a central processor which could be kept continuously apprised of the latest sta of play. Supposing improved management and technique existed, just how wou data co-ordination help? One obvious way is to identify more closely the informatic sought, e.g. 'What are the co-ordinates of component A in location B?' or ideall 'Is the space C in location B vacant?', 'Is the information in vehicle E modified?', 'Are resources F required at time G?' That is, data co-ordination could lead to relatir

performance to systems, commodities to locations, and activities (or information) to time.

4-36 Designers frequently generate new designs rather than adopt existing ones that have performances meeting the requirements of the brief. This is an expression of the creative urge that has made them into designers but it does in part stem from difficulties encountered when attempts are made to retrieve past designs (together with their performance). Whatever the reason, the practice must often be expensive to all concerned. Alongside endeavours to reduce the variety of components, a study is being made—and was referred to in Chapter 3—of the feasibility of having standard details for many parts of buildings, junctions in particular. To be effective such details must be retrievable along search patterns acceptable to designers (building element x construction technique) and their performance must be categorised: both rôles for data co-ordination. Similar arguments may be applied to the case for standard specifications, and for standard preliminaries and preambles to Bills of Quantities, all of which could be called forward into production information by instructions initiated by details about the building type, the technical solution, the building element and the work-piece.

4-37 The needless regeneration of data by different users must be avoided. Ferry has shown that any part of a project is 'measured' on at least five (and sometimes seven) occasions[31]. This may be remedied in two ways. The first, stemming directly from data co-ordination, involves presenting information in ways compatible with users' requirements. The second is more subtle, often requiring the collaboration of two participants, structural engineers and quantity surveyors or clients and manufacturers.

4-38 Hence the rôle *to support information flow* and achieve economy can be restated as:

to identify, for various users, the ways in which information should be structured in order to meet their requirements and to avoid interpretation into another form

to establish a structuring for the documents* used in the industry

to identify the categories of information relevant to each document

to provide systems of cross-referencing between documents

to establish a framework for accepting, identifying and categorising standard details, and specification, preliminary and preamble clauses

to provide the means of co-ordinating such standardisation

to provide the means of making methods that allow the multiple use of data known and adopted

* Briefs, letter of appointment, enquiries, invitations to quote/tender, drawings, specifications, Bills of Quantities, estimates, tenders, programmes, project proposals, resource schedules, progress reports, costings, etc.

Chapter 5

Practical and technical considerations

5-1 Thus far the discussion has taken account neither of the practical circumstanc that data co-ordination must satisfy nor of the human and technical factors that w affect its adoption. These matters are of utmost importance because systems co-ordination and coding exist for practical purposes. Hence the aim of this chapt is to derive those criteria that systems of data co-ordination and coding must me if they are to prove acceptable to the industry.

5-2 The essence of the report is that related systems of data co-ordination should b encouraged in different sectors of the industry. Hence the benefits obtained w depend very much on which sectors grasp the initiative and on the enthusiasm ar effectiveness of the response of the practitioners who see the facilities as a sprin board for developing new methods of working and new relationships. Any attemp at overall cost–benefit analyses would give the report a spurious exactitude. This not to argue, of course, that cost–benefit analyses should not be attempted befo any specific stage is undertaken, for the circumstances will then be adequate specified.

5-3 The chapter divides into five sections: practical considerations, commercial consider tions, human factors, vehicles of communication, and computer considerations especially the likely availability of computers and data links to the industry.

Practical considerations

Systems* must be capable of being implemented in stages

5-4 A decisive argument for a 'continuous creation', rather than a 'big-bang' approach data co-ordination is provided by the size and variety of the industry and by constant evolution. There are many requirements for information, and differe advantages are to be gained from different types of data co-ordination. In sor sectors, structural engineering for example, benefits are related to technical pr cedures that increase the speed and power of analysis and design; in architectu design, there is a pressing requirement for effective data retrieval by search procedur reflecting architects' interests at different stages of design and for simulation mod allowing man–machine interactions; other functions, design realisation and co tracting for example, are concerned more with the aggregation of information in meaningful bundles and with improving transactions between the construction a the supply industries. Each sector will call for a different, although related, approa to data co-ordination and coding, and it is reasonable to suppose that practitione will be most inclined to take the initiative if they are not constrained by an overridi necessity to await the development of a unique system that may not meet th particular requirements.

5-5 The development of a unique comprehensive system, even if technically possib would require a considerable outlay before any advantage were derived by a sector of the industry. Experience of attempting to raise subscriptions for informati services for the industry has shown how difficult it is to extract contributions unle an immediate advantage can be seen; a not unreasonable point of view. Smal developments to meet particular needs would be easier to finance.

* System in this context means a system of data co-ordination and coding

Systems must be capable of being hospitable to separate but related sub-systems

5-6 This follows immediately from the above.

5-7 The provision of more and better project information is an expensive matter. It is therefore probable that any system or sub-system will have to be of such a form that it can be applied in different ways on large and small projects, and on projects with considerable repetition. For instance, experience in Denmark and United Kingdom has shown that hospital design benefits from the preparation of room schedules showing the finishings and contents of every room, because these are largely dictated by the requirements of a central authority, and because of the large number (sometimes 2000 or more) of rooms in a project. Schedules of equal comprehensiveness are not operationally essential on smaller projects, although they may confer advantage to the project team. Similarly the provision of lists of materials in trade terms in Bills of Quantities may be feasible in system building, where 'unit' quantities can be taken-off and re-used on many occasions, but not practicable within the present fee-scale on other projects. Again, contractors specialising in a limited range of construction methods might find it advantageous to prepare formal written instructions for chargehands, because these could be used on many sites.

5-8 The very diversity of the industry is going to create a need for parts of the system to be developed in different degrees of detail to answer different questions.

A system must include the means to promote and co-ordinate its development

5-9 This requirement follows from the foregoing. Implementation in stages will entail the encouragement and co-ordination of the separate activities of groups within the industry. It will also require advice and the provision of information, the promotion of data co-ordination, the creation of a forum for discussion and agreement of principles, and the resolving of disputes.

The system must involve the industry

5-10 Data co-ordination is more than the mere ordering of words and the classification of things and concepts. Broadly, it stems from the way in which the industry goes about its work, design and management in particular. Because of this, the industry cannot be indifferent; it must be closely associated with, and be part of, implementation. None can afford to be indifferent because the consequences of data co-ordination and computer application are likely to extend right across the field from education and training to the general and technical aspects of design, to communications, to the management of construction, and to the transactions between the construction and other industries.

Commercial considerations

A system should not cloud the responsibilities of participants

5-11 Responsibilities are incurred as functions are discharged, and it is important that the effect of systems on the responsibilities of participants should be quite explicit. For example, although the functioning of an inter-active design team may lead to better decisions than would have been reached had the team members worked separately, combined working might make the allocation or the acceptance of responsibility uncertain. Similarly, if contractors are provided with production information grouped in ways convenient to them, the groups selected must not make implicit decisions about the construction methods used or about the deployment of resources, without also implying a limitation on a contractor's responsibility for these matters.

A system must preserve commercial and professional security

5-12 This is necessary to ensure that procedures developed by one organisation will n be immediately and freely available to many, and that details of private commerc transactions cannot become public knowledge. When an organisation has devis a procedure and related computer programs to design, or to calculate, or to co perhaps using sub-routines already written from the stand-point of that organisati it is highly desirable that the procedures are used only by them. From other stan points it would be to the advantage of all to have effective procedures made genera available. The remedy may lie in some extension of the copyright or patent la together with a means of rewarding individuals and organisations whose procedur and programs proved generally useful.

Human Factors

Implementation of systems should include prior consultation with those directly involved

5-13 The report thus far cannot be read without it becoming clear that its implementati will bring changes in the working methods of the industry. So, of course, will t extended use of computers, quite apart from the measures to which the rep points, and the industry is in any case always evolving.

5-14 Changes of complete organisations—for example through computerisation, manag ment reorganisation, or adoption of new languages such as coding systems—a necessarily more disturbing than sub-organisation changes because they invol the control process itself—the central nervous system, as it were.

5-15 Resistance to change will be less when those directly involved feel that they ha contributed to the development and have a vested interest in its success; the 'n invented here' response is thus avoided. To the extent that this is not possible, attempt should be made at or before the inception stage to facilitate by consultati and conversion processes the performance of new functions. It is here that simul tion exercises, involving all levels of the hierarchy concerned, could be most useful.

The characteristics of a system should be acceptable to users

5-16 Allowance should be made for the background of the people affected and the gene principle here is compatibility. Each group has its own characteristics and, if possib the new control process or languages should be adapted to the interests, prejudic and experience of the participants. For instance, those with a drawing-board bac ground are likely to be attracted more to graphic than to numeric displays, whi engineers are likely to find a numerical approach more attractive.

5-17 Many people have a natural resistance to any innovation that detracts from what considered to be their central function, and this is particularly true for designe Therefore, it is important that systems permit a man-machine dialogue. Thus, a computer graphic system should be able to retain on display a whole array whi part of it is manipulated or changed in scale. For the same reason, both graphic a numeric programs should be arranged so that a program can be interrupted f an intermediate print-out if this is shown to be desirable.

Implementation of all or part of the system must be supported by adequate training

5-18 The requirement to involve those who are to be affected by a new system with t system before its introduction carries with it a requirement to mount training scheme Experience has shown that training is required by all levels of an hierarchy, if t enthusiasm of all is to be enlisted. Naturally, such training must be attuned to t scale of interests of the different users. Also the timing of training should be such th

all have an early opportunity to practice their newly acquired skills in their working environment; failure to meet this requirement results in a loss of interest.

5-19 In the long term, education and training can contribute to, and be assisted by, data co-ordination. One consequence of data co-ordination is to obtain a more ordered view of operational requirements, which should enable a better match to be made between training and the demands to be placed on trainees by the industry. Hence a sharper distinction may be drawn between education and training, with the latter more clearly focused on current requirements, with a provision for re-training as they change.

Vehicles of communication

5-20 The principal function of a vehicle—most usually at present a document—is to convey information to other participants, enabling them to carry out foreseen activities. When the sender understands the activity and the recipient's information needs adequately, the vehicle will carry the relevant information and the recipient will understand the sender's intentions. This understanding can develop with long established associations, and when opportunity is given for recipients to state their information needs; if these circumstances do not exist, the sender can do no more than imagine the needs and deal with complaints and questions as they arise. Whether intentionally or not, vehicles convey not only information but also impressions.

5-21 In some cases, information is transmitted to only one recipient; frequently multiple copies of one document will be the vehicle by which information is passed to several recipients, all with different needs, and none of whom may need all the information it contains. If the sender understands the needs of all the recipients, and if they all can easily extract what is relevant to them, this can be economical. There is room, however, for studies of ways in which essentially the same fully detailed drawing could be modified to accentuate the information needed by particular recipients [1].

5-22 One document will rarely contain all the information needed by a recipient for an activity and he will usually have to draw on information conveyed in other vehicles. Cross-referencing to these other vehicles will be an advantage, but if the information consists of frequently-quoted items (e.g. specification clauses, standard products and commonly used details) experienced recipients will not need to consult them at all. For operatives the most effective information is that which forms a mental picture of the work-piece and identifies the resources needed. Photographs, models or sketches supplemented by verbal instructions and the minimum of references to other sources may be best for this purpose and this approach may also help at earlier stages in the project.

5-23 Many documents serve further purposes beyond conveying information for immediate use by others. They may form a convenient compendium of information serving the originator's interests primarily and their usefulness to a possible recipient may be secondary. A detailed schedule of requirements, against which can be entered what has actually been provided in a design, may form a useful checklist for designers, although no other person may see it. Large-scale cross-sections through buildings, and elevations of every internal or external wall surface, although not necessary for the purposes of construction may be valuable aids to a designer in assessing the quality of his own design. Drawings of the layout of all piped services in a building (particularly at places where they compete for space) enable the feasibility of proposals to be checked. Comprehensive schedules and drawings also serve to record design decisions and contractual agreements, for reference in connection with other projects. Such omnibus documents may be much less helpful to any recipient than they are to the originator. Recipients can act more easily and with less chance of error from a document containing only what is relevant to their needs, with all extraneous information ruthlessly excluded. This is made possible with some mechanical techniques, e.g. computer scheduling and multi-colour printing.

5-24 To complement the information contained in documents specific to one recipient, general arrangement drawings are useful in showing the context of particular work.

These are common in other industries, and their equivalent in building is the set 'eighth-scale' drawings (1:100 metric) or larger which are the vehicle by whi information is passed for such diverse purposes as obtaining approvals, instructi specialist designers, planning construction programmes, allocating space and layi out furniture.

5-25 Transmitting or recording information may involve one or more of the followin

Written descriptions e.g. specifications of products, workmanship or perfor ance; bills of quantities; schedules of requirements, material resources, plant; contracts; letters; instructions on packages

Drawings using orthographic or pictorial representations, supplemented dimensions and words

Models, samples, mock-ups to reduced scales and to full size, indicati assembly methods, textures and standards of quality

Jigs, storey rods, templates

Photographs and cathode ray tube displays and films indicating produc details, construction sequence etc.

Verbal descriptions and demonstrations (generally appropriate only to i structions to operatives)

Punched paper or magnetic tape from which other vehicles can be produced

5-26 In selecting and determining the circulation and information content of vehicles, t following criteria are relevant:

Adequacy: A vehicle should contain all the relevant information to enab known recipients to carry out specific activities giving, where necessary, cros references to other vehicles, including any that will show the activity in its f context.

Clarity: A vehicle should display all the necessary information in the manr most useful to the recipients, so that they can grasp quickly what is required f them, without unnecessary searching among information intended for othe Where information which the recipient might expect to find is omitted, or whe a particular decision has been delegated to the recipient, the fact should noted.

Reliability: A recipient should be able to proceed in the knowledge that t information contained in a vehicle is accurate, feasible and up-to-date.

Economy: The production and transmission of information should be efficie in the use of the originator's resources, and of the recipient's. The possibil of multiple use should be exploited.

5-27 These criteria are difficult to satisfy in their entirety in an industry structured as now is and within which information is transmitted almost entirely by manual mea (however much computers may be used within separate organisations). The lack opportunity for some types of recipients (especially operatives) to state their inform tion needs, the delays in preparing and transmitting information, especially that supe seding earlier information, and the need to assume or regenerate information alrea produced by another participant but not recorded or passed on, or passed on but n in a suitable form, all prevent these criteria from being met. It is relevant here to reminded of the complex nature of the industry, which encompasses those of ma skills and of divergent interests, joined by a variety of formal and informal ti temporary and permanent.

Computer considerations

5-28 In discussing the type of computer system that might be incorporated into the futu information system of the construction industry, it is first necessary to have a rou idea of what the information system might be like when the computers are us

widely, what quantities of information will be transferred and what types of files might be required. From the study it is not possible to have more than a rough outline of the possible overall information system. However, to deal with it in very coarse detail, as far as the file structure is concerned, should be sufficient for our needs. The main purpose of this section is to indicate what equipment is available now, and possible future developments, so that those who are interested will have a background against which to pursue their own particular interests. Present needs seem to be well covered; optical presentation and transmission of drawings will need some further development.

Possible computerised information system for the construction industry

5-29 Fig. 11 shows the major on-file documents which are suggested by the study as being part of an information system and it also indicates some of the sources of information and the major interactions between on-file documents which will help co-ordination.

Design software

5-30 This is at present very fragmented and includes many programs useful for design such as structural engineering and design simulation programs. In future these should present no storage problems and transmission rates (speed and quantity of information) between user and computer need not be high unless graphic information is communicated.

Project file

5-31 Since this is the main co-ordinator of the design and construction processes, the diagram indicates that the files of contractor and designer should be capable of being merged at the earliest possible stage of a project, although this may have to be after tender acceptance in the case of competitive tendering. The combined file would then be a point of collection for a description of the project including lists of work-pieces with links to drawings and locations within the project. It should be fed with data from the various designers, and at a later stage by the contractor, and it is envisaged that much of the product information should be easily transferrable from a central commodity file or from the 'designer's reference file'. Uses of the file will include cost estimating, scheduling of items, contract documentation, programme planning and a project evaluation on completion which can be transferred to the 'designer's reference file'. If the file is to contain a detailed description of the project including construction site operations, then for larger projects it may well exceed 10 million characters which would require quite rapid direct access for some of the suggested uses of the file to be achieved. Computers with disc facilities would seem adequate. Since one of the purposes of having a collective file is to eliminate repeated input of data then transmission rates can be modest, say a peak rate of 100 000 characters/day for a large project. (The 'character', abbreviated to 'char', is the unit of storage in computer files and is approximately equal to one alphabetic or two numeric characters).

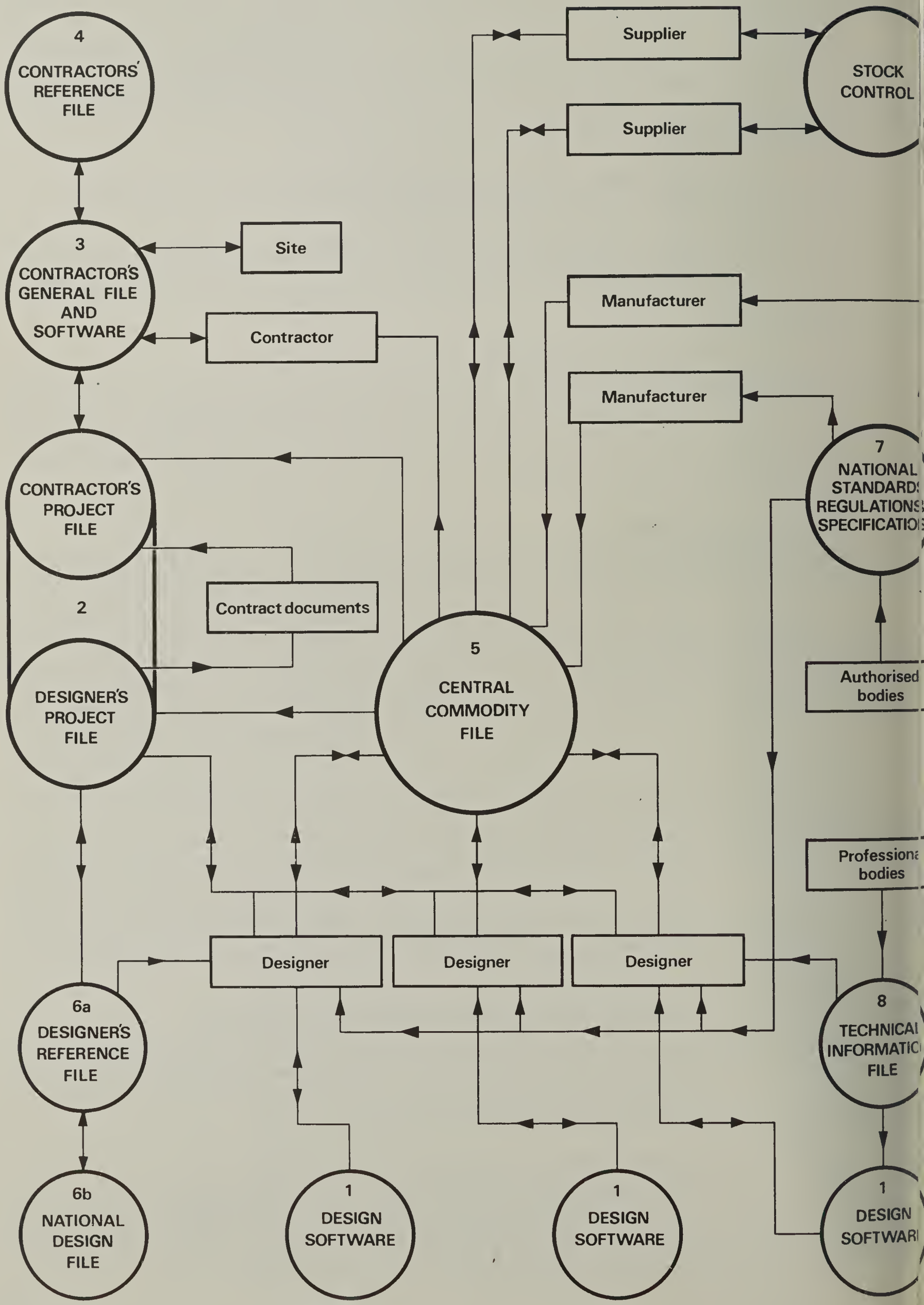
Contractors general file and software

5-32 This part of the contractor's system will have software for such procedures as project planning and resource allocation as well as containing private information on the contractor's operations. Some of the information for the file will be derived from site recordings and project contract documents.

Contractor's reference file private

5-33 Generally this will contain confidential information used to price and programme contracts. Information input will include a processed form of site information giving labour times and plant requirements for operations. In addition it may have stored standard rates, bonus rates, etc. The file size should be quite modest, say one million characters.

Figure 11 Possible files and relationships in information system



Central commodity file

5-34 This will be a very large body of data provided by manufacturers about their products. Whether it will be confined to products of interest only to construction or to all products will depend on the collaboration between the various possible users of such data banks. Certainly the designers and contractors will require access to this file for the selection of products. Such a file could be linked with the files that would be held privately by suppliers to indicate discounts and credit ratings of customers. CEIR in their report on 'Commodity coding' have estimated the size of commodity files as being up to 2600 million characters with about 1 million commodity records of about 2600 characters each. However, as far as the construction industry is concerned, although a fully comprehensive file might be comparable to this, a much smaller central file should still be very useful—one of 100 million characters would give a coverage similar to the Barbour Index. The problem of updating and the costs of storage devices for such quantities of readily accessible data suggests that the industry should have only a few central computers carrying this information. Communication channels required by individual firms to use the files would not seem to require high rates of transfer, particularly if individual organisations were to have microfilm facilities of the kind mentioned in paragraphs 5–52 *et seq*.

Designer's reference file

5-35 It is possible that two types of design files should be distinguished; one an 'individual designer reference file', the other a 'national design reference file'. The reason for having the first is that it could be used in a similar way to present design methods whereby the designer first attempts to select commodities or design constructions of which he has some personal experience. This file therefore would be used for feedback and might contain from previous projects information such as the project brief and a summary of resources used with links to the drawings (or the drawings themselves), cost estimates and prices. The size of this file will largely depend on the degree to which the information on the project file has been summarised.

The national design file might include information on all large building projects but presumably at a lower level of detail than the individual file. Another class of information that might be part of the national file are sets of standard detail drawings. File size is difficult to estimate but on an assumption that the file were to include information on the largest 10 000 projects each year, with about 10 000 characters for each, a size of 100 million characters a year seems to be reasonable. With such a file the use of a large central computer would seem logical. For the standard building and engineering details an estimated 5000 drawings should be adequate. If only the essential geometry is stored, such as the co-ordinates of end points of straight lines so as to output a line diagram of the building, then this part of the file should only be about 10 million characters, which puts it within the present capacity of exchangeable disc and therefore amenable to medium sized computer installations: alternatively these may be held in a microfilm store (see paragraph 5–52).

National standards, regulations and specifications

5-36 The standards and regulations would be used in conjunction with the central commodity file by both product manufacturer and designer and the regulations and specifications would be used by the designer and contractor in conjunction with the project file while selecting products, during preparation of contract documentation and in ensuring the design complies with regulations. The storage requirements of these files, which require direct access, should be only a few million characters and therefore within the handling capacity of medium sized computers.

Technical information file

5-37 Technical information of the type at present contained in design manuals and provided by the professional bodies could be computerised for quicker access and greater flexibility of updating. Estimates based on present technical manuals suggest that this file would probably be of about 10 million characters, and that it would require rapid access.

Computers

5-38 Key factors which will decide how far and how quickly the type of computeris information system suggested by Fig. 11 will be developed are the costs a capabilities of storage of information on computer and the costs of communicat between the files of data or between the users. The demands made by the inform tion system for central processor operating power is difficult to assess but pres processing power would not seem to be a serious limitation on the feasibility of information system and with the rapidly progressing computer technology sho be even less likely to be a limitation in future.

5-39 The characteristics of stores will be discussed first, and then those of links.

Core store

5-40 This is the storage medium with the most rapid direct access but is also the m expensive with an approximate cost of about 6 char/£ for a store with direct acc time of 1 microsec. One of the main limitations imposed by the core store size is the software—the compiler language and the size and complexity of other p grams used—since for efficient operation the whole of the program being u should be within the core store. For instance the software required to com programs written in a high level language such as Cobol can require in excess 60 000 characters.

Fixed magnetic disc or drum

5-41 Fixed disc facilities can at present be obtained with capacities of up to 400 mill characters with direct access to any part of this information in about $\frac{1}{10}$ sec a transfer speeds are typically about 200 Kchar/sec. Costs for this type of facility in the region of £100 000 with storage cost at 1000–3000 char/£. The larg magnetic drums are comparable to the discs in both capacity and speed of acc but smaller capacity drums can give shorter access times and are more costly character of storage.

Exchangeable disc

5-42 These are able to cope with blocks of information of up to about 8 million charact at a time on each unit which can be directly accessed in $\frac{1}{10}$ sec, similar to fixed dis Costs of facilities are at present in the region of £20 000–£60 000 with abu 200–500 char/£. The disadvantages of greater cost per unit of accessible storage w lesser files compared to fixed disc is offset by the fact that the disc pads used exchangeable with the costs of storage on additional discs as low as 30 000 char

Magnetic card file

5-43 These are similar in function to fixed discs and drum units but can be larger. Syste with 2500 million characters are possible at present, and have a lower cost for stora with about 5000–15 000 char/£. The minimum viable unit costs about £70 0 These advantages are gained at the expense of a slower direct access time of ab $\frac{1}{3}$ sec, a lower reading speed, and at present a lower mechanical reliability.

Magnetic tape

5-44 After meeting the cost of the control and tape handling equipment which w usually be of the order of tens of thousands of pounds, the magnetic tape itself i most economical form of storage with almost a million characters/£. Howev average access time to any part of a given tape containing up to 50 million charact can take several minutes, therefore magnetic tape is mainly useful for tasks requir serial access or as an additional storage medium for safety purposes.

Transmission of data

5-45 If we are to avoid translations from one form of code to another in the informat system, then there will be a need for data links between the various participants a computers. For good co-ordination many of the communications will require to more immediate than the dispatch of tapes or cards though this will provide a che and flexible service. Data transmission services provided by the GPO are an obvio solution though what type of service is less obvious because of the variety of tar

and operating methods which will depend mainly on line quality, distance; flexibility required and the type of equipment used at the terminals. Point-to-point private lines are likely to prove uneconomic as links for communications between participants, except for the largest projects, since in the traditional building process these links are numerous with the sets of participants engaged in various projects being different, and at any one time a participant may be engaged in several projects. It also takes some time to establish private lines at present. Using the STD network with data terminals provided with MODEM* equipment would seem to be the appropriate flexible means of communication although ordinary switched telephone lines are not of guaranteed or uniform quality, a factor which is not a serious disadvantage when operating with a transmission rate of equivalent to less than 100 characters/sec. Where immediate response is required private lines may be the only solution. Some brief notes of uses and costs of some of the GPO services are now given.

Datel 100

5-46 This is suitable for teleprinter links of up to about 7 characters/sec using the public switched telegraph network (Telex) or a private telegraph line. The Telex network although cheaper than the switched telephone network (STD) presents more difficulties in making connections. Typical operating costs of a teleprinter terminal including depreciation of equipment will be in the region £800–£1000/annum.

Datel 200

5-47 This uses a MODEM with a rental of about £100/annum for each terminal and this is connected to a standard telephone installation or private speech circuit. It is suitable for teleprinter links where the flexibility of the STD network is advantageous and it is capable of handling 25 characters/sec. Typical annual costs of operation of a terminal including depreciation will be greater than £1000 with a cost of about £2000 for transmitting 100 000 characters/day over 50 miles or 200 000 over 30 miles.

Datel 600

5-48 As this is capable of operating at equivalent to 75 characters/sec on the STD network, or at higher rates on private lines it is a possible choice for a wide variety of terminal equipment uses such as paper tape readers and punches, magnetic tape input and output, CRT with character displays, punched card equipment, lineprinters and document readers. This type of equipment can only be economically justified if large volumes of data transfer are required, say greater than 300 000 characters/day, since overall costs are likely to be greater than £2000/annum mainly due to the higher cost of terminal equipment.

Datel 2400

5-49 Video displays operated remote from a large central computer in a 'conversational' mode and using graphic techniques are likely to require greater transmission rates than Datel 600. The Datel 2400 service should meet these demands but does entail the use of private lines with tariffs alone of £3000/annum or more. It can of course have similar applications to the Datel 600 service but operating at much higher speeds.

Computer–computer links

5-50 Direct links between large computers to be efficient with computer time should be capable of carrying much higher transmission rates than any of the above services, rates of the order of 100 000 characters/sec being preferable. To cover such requirements at present entails the use of special facilities which are undergoing active development.

Computer graphics

5-51 Transmission of graphic images does require transmission of vast quantities of data much of which is redundant information for simple drawings. This can be much reduced by using a small computer at the terminal to generate the image from more essential data transmitted from the central computer. Only then will quantities of

* MODEM—a device for converting binary information into a modulated signal for transmission along telephone speech circuits

transmission be small enough to be met by the Datel services, of which Datel 6 is likely to be the smallest capable of dealing with the quantities involved.

Microform

5-52 Microform techniques include a variety of methods for producing graphic or textu documents in a much reduced form. Their potential for improving the disseminatic storage and retrieval of information is considerable and they are likely to play important part in any information system of the future. In particular they provide means of overcoming the problem of high transmission costs for graphic informati by enabling vast quantities of graphic information to be located close to the user modest cost. (For a comprehensive survey of the field see reference*).

5-53 To deal with accurate scaled design drawings of large size requires the use of 35 m or 70 mm film equipment; systems based on 35 mm aperture cards—usually 80 column size card holding a 35 mm frame—are now quite common in engineerir This type of equipment, however, is more costly than retrieval, reduces costs a simplifies methods of printing at reduced scales and also enables originals to produced on cheaper materials. Costs of installations with camera, film processir reading and enlarger/printer equipment are likely to be £3000–£10 000 and ther fore only economically viable in the larger design offices.

5-54 For normal printed documents and drawings, where precise scaling of prints not essential, 16 mm film is used generally in the form of rolls of about 100 ft co taining 1000–3000 pages or microfiche (A6 size i.e. about 6 in x 4 in) containi 40–100 pages. Camera costs are typically £400–£1000 with recording costs of le than 1d/page and the cost of copies, when produced in large quantities, will l mainly that of the film (about 35 shillings/100 ft) with an additional 15 shillings so if cassette loaded. Costs can therefore, be as little as $\frac{1}{8}$d to $\frac{1}{4}$d per page. Costs readers range from less than a hundred to several thousand pounds: for instance thousand pounds will purchase a reader capable of automatically selecting particular page of a cassette loaded reel (1000–3000 pages) in less than 10 seconc and at the touch of a button able to produce an A4 sized print (cost 4d–8d) in further 10 seconds.

5-55 Production of photo-chromic micro-images (PCMI) is a more recent development which 3000 pages can be compressed onto one A7 sized microfiche. Producing master copy costs about £300 but thereafter copies can be contact printed for 8s 4 each. Thus 2000 copies with master copy cost 1 1s 6d each. Readers for this mediu are available for about £300 and these enable retrieval of individual pages by manu movement of the fiche carrier using two dimensional co-ordinate references f positioning. PCMI would appear to have potential applications for the centr commodity file, national design file including standard detail drawings, nation standards file and technical information file (i.e. files 5, 6b, 7 and 8 of fig 11) with library of all the information contained in these files deposited with each user. Th used in conjunction with a link to a central computer could prove to be a powerf tool since the flexibility of indexing and searching on the computer would ease th requirements for updating the more static microform library. A reader with automat fiche and page selection—a device not yet developed for PCMI—would ac considerably to the attractiveness of such a system if professional design staff a to use the reader.

5-56 Colour microform is still being developed and when marketed in this country w probably cost 3 to 5 times as much as black and white. Even so, manufacturers commodities might find it attractive for use in commodity information and the poss bility of colour in the central commodity file could be a significant factor in its gener acceptability.

* Evaluation of microrecording techniques for information and data storage and retrieval. B. J. S. Williams. Hert 1967. (Obtainable from National Reprographic Centre, Hatfield College of Technology).

Videotape

5-57 This is a type of microform with picture images impressed onto magnetic tape with one reel of magnetic tape holding the equivalent of a few hundred thousand pages. However, capital costs of videotape handling equipment are more than £100 000 and therefore applications in this field are likely to be limited to central facilities probably in conjunction with a central computer.

Chapter 6

Coding aspects

6-1 This chapter is inserted partly as an introduction to coding for those who are int ested, and partly to adduce certain criteria for an information system that are parti larly relevant to any coding system or systems that might be applied to it.

6-2 The types of code discussed in this Chapter must be distinguished from the compu languages such as Fortran, Algol and Cobol etc. which are used for specify computer programs and are sometimes referred to as computer codes. A *code* the context of this report may be defined as a set of symbols grouped or ungrou which may be used to facilitate the storage, transmission or manipulation of inf mation and data—codes for secrecy purposes are not considered. The symbols code will often be arranged in groups with each group having significance. Th groups will be referred to as *fields* of the code, e.g. English words are fields of varia length. In some codes, the format and the order of the fields are fixed, in oth the format can be varied, or the order changed or both.

6-3 The process of generating a code from the original form of information or data *encoding* and the reverse process of transforming the code into meaningful inform tion is *decoding*. Both encoding and decoding require the application of the *co key* which is a set of rules and equivalencies to enable these processes to be pr formed.

6-4 With the above definition of code it is clear that any communications either betwe people or between people and computers use code. Natural language is included a code by the definition though it is rather special in that the key to the code relat concepts, words and sentences is largely in the human memory and it is difficul separate concept from the language. Merits and demerits of different types of co will often be compared to the special case of natural language.

General benefits of codes

6-5 Some of the benefits which different types of codes can be designed to give are compress information, to increase accuracy of transmission and interpretation a to enable a variety of types of manipulation to be performed.

6-6 Compression of information, which can reduce redundancy, leads to econo of transmission and storage of information, and may also improve the speed of int pretation. However, it can, if taken to extremes, lead to loss of accuracy in tra mission; redundancy, on the other hand, can sometimes lead to the detection a correction of transmission errors. For instance, messages in English with a f spelling errors or even words missing may still be interpretable because there redundancy in the language.

6-7 Three methods of producing shorter forms of information than natural languages distinguished here.

1 To list items of information used, or likely to be used, and code each with shortest set of symbols possible, thus removing redundancy within the code fiel English even at the level of words has much redundancy of letters—there are o 450 000 (i.e. 26^4) distinguishable fields with 4 letters, yet few of these are used words, and most words have more letters.

2 To analyse the usage of information in documents and produce the short documents by making the length of code fields dependent on the frequency

occurrence, with the shortest sets of symbols used for the most commonly occurring information. Morse code is a notable example where only two types of symbols are used, the 'dot' and the 'dash' and each code field corresponds to a character symbol. Natural language words also display this feature to some extent in general usage, but in specialised uses the frequency of information may be quite different with many long natural language descriptions occurring frequently. In construction this type of document compression is already used. Examples are:

Standardisation of products and specifications enable short references to be used in place of large blocks of information

Identity codes where non-significant code numbers are used to represent products, specifications, etc.

Short coding techniques of the type using ad hoc codes or page numbers in documents.

3 To select only the most relevant information used. Classification is a natural starting point for this process in which the most important *characteristics* of the information are chosen, and information is grouped according to them. Codes may be used in place of the natural language description to enable further compression or to facilitate manipulation of the information such as ranking or groupings by simple mechanical processes.

6-8 Accuracy in communications may be aided by using codes with code keys for both encoding and decoding which are in a language appropriate to the users discipline. Errors arising in transmission may be detected by introducing pieces of code at encoding for checking purposes at decoding. Simple checks can be devised adding little extra to the code yet having high probabilities of detecting particularly commonly occurring errors. For instance, transposition of adjacent digits in a section of numerical code can be detected by adding a check number, derived by alternately adding and subtracting the digits.

6-9 Codes are often desirable for the purpose of carrying out manipulations

To enable items to be ordered in a way useful for working through sequentially

To make useful groupings of items

To facilitate retrieval from large banks of items

To enable the destination or user of information or items to be clearly identified.

6-10 Manipulations can be achieved without the code, which carries the information, having the manipulations expressly stated. However, if this is the case then some key (index) which carries a prescription of the manipulations required must be used at the time of performing them. For instance, in the use of computers for grouping information, the input data may be plain language words, but the computer would have to store a key associating plain words with the desired groupings.

6-11 Some of the facetted codes used by quantity surveyors for producing Bills of Quantity are examples of codes designed for the first two purposes where many of the manipulations are expressly stated in many of the facets, thus enabling simple sortations to be performed giving a variety of useful orderings. There are also quantity surveying codes which do not expressly state the manipulations required to obtain Bills of Quantities but require the computer to hold an elaborate key which is applied before the Bills can be produced. The Ministry of Public Building and Works have such a code with facets consisting of conventional abbreviations of English words.

Documents

6-12 Before discussing in more detail the merits of certain features of codes in relation to users and computers it is worthwhile to discuss documents, where document is defined here as 'a collection of related items of coded information'. For information systems making use of computers the following three categories of documents are meaningful.

Input documents

6-13 These are the documents that could be used as input to computers and therefore a intermediate between user and computer and may be considered as data input. the construction industry, these input documents might be in a variety of forms. The could include drawings, lists of coded information describing a project, performanc data of products and materials, commands instructing the computer to perfor operations such as design calculations, retrievals and updating of on-file document output of file information, intermediate input documents, etc. Intermediate inp documents such as information on punched paper tape, punched cards and magnet tape are intermediate in the sense that they are used between hard copies (e.g. th printed page) and the computer.

On-file documents

6-14 These consist of coded information stored on computer media such as magnet tape, magnetic discs and drums, processor working store, etc., and which are inte mediate between input and output.

Output documents

6-15 These are the products of the computer used by humans. They might include drawing computer printed output and visual display generated by the computer.

General criteria for designing codes for documents

6-16 The general criteria on which codes for input documents should be based are follows:

Accurate production and checking of codes should be easy. This implies th encoding procedures should be appropriate to the skills of the persons involve and that the time needed for referring to code keys should be minimised

They should be short for economy of input document production (writin punching etc.) and computer input time

Symbols appropriate to computer input devices should be used

Computer time for input codes to be translated into on-file document cod should not be excessive.

6-17 Codes for on-file documents should be:

Short for economy of storage and internal computer transfer time

Suitable for the types of file processing required such as retrieval, sortin producing output in order to minimise processing times

Both of these requirements imply that the codes will make use of the natural arrang ments for storage of information within computer storage media.

6-18 Codes for output documents should be:

Easy to interpret by the user and therefore appropriate to his skills

Appropriate to the computer output facilities.

Some features of codes

6-19 In this section particular features of codes are discussed which should give sor guidance in the matter of how far codes will differ from the usual means of commur cating in English.

Natural and restricted language

6-20 The use of natural English language with its ambiguities and choice in the modes expressing concepts is in the foreseeable future likely to be an impracticable way

communicating generally with computers. The reason for this is that no sufficiently good definition of natural language has been developed to enable computer software to carry out simple interpretative tasks let alone the variety of tasks that could be required for the construction process. Therefore the most comprehensible form of communication between man and computer might be to have input documents composed of words from a restricted vocabulary which is a preferred list of words with no ambiguities of meaning and with the relationships between words such as synonyms clearly defined.

6-21 The advantage of using such a vocabulary would be that input and output documents would be interpretable without reference to a code key, though of course reference may have to be made for selecting preferred words when producing input documents. This will be a considerable benefit when Optical Character Recognition or speech recognition devices are widely used for input since then only the printed document in restricted language need be prepared and stored.

6-22 Some of the disadvantages of using English words are:

Owing to the excessive redundancy in words, documents will be longer than necessary resulting in greater time and cost of production of input and output documents and greater storage space requirements for on-file documents

The software required to interpret input or process on-file documents will have to incorporate all the relationships between the permitted words and, unless input documents have lengthy collections of ordered words to describe each piece of information then few manipulations and groupings will be carried in the input and the computer will have to have complex software to carry out these tasks. For instance distinguishing between a description of a labour item and a component or material to be incorporated in the building would require severe restrictions on word ordering as well as many checks on the types of words used. Use of readable English in output documents should not require complex software and should not be difficult to provide on computers with sufficient readily accessible storage

Natural language words are of variable length and will have some of the disadvantages of variable length format codes.

Although the redundancy in language enables some checking for error detection, the facility of checking non-language codes by using the computer to give a language translation of the coded information is less useful and some errors might therefore be more difficult to detect

Codes based on a restricted English will not be international and it may even be difficult to select words which have the same meaning to different branches of the construction industry.

Mnemonics of language words

6-23 Mnemonics of natural language words will have the advantage of compactness and therefore will be more economical for transmission and storage of information than language, yet they should still be easy to interpret without reference to code keys. Mnemonics if so desired can be of fixed length and therefore have some of the advantages of fixed format such as facility of storage on files required to be accessed frequently and uniformity of presentation in input and output documents. However, the use of simple rules for forming mnemonics from language words can lead to ambiguities with two or more distinct words giving the same mnemonic. More complex rules may be used to avoid this but may result in losing some of the advantages in the ease of formation and interpretation.

Use of numeric and alpha characters

6-24 It is to be expected that input and output documents communicating information about quantity (i.e. statistics) will not be coded solely in words but will make appropriate use of the numeric characters or graphical means. Many of the codes already developed are confined to using only numeric characters in input documents. The Herts C C/Crittall code for communicating information about windows between

designer and manufacturer is purely numeric and so are the Brisch codes develope mainly within the engineering industry. This section spells out some of the advantag and disadvantages associated with using alpha and numeric characters in codes f computers.

6-25 Restricting codes to using only the numeric characters may have the followir merits:

Less training should be required for typists to type numerical information ar typing speeds may be higher. Although there are methods of presenting infc mation input such as graphic displays not requiring a keyboard, the keyboard likely to remain the chief method of preparing code in a form suitable f computer input for some time

Providing check digits for numerical codes should be easier than for mixe alpha numeric codes

Putting numerical coded information in order should be easier than with alpl codes both for humans and computers

Cheaper machines could be produced for dealing with a limited character s such as the numerical characters. For instance reliable Optical -Charact Recognition devices are likely to be developed firstly to treat numerical and few other easily distinguishable characters and such restricted devices shou be cheaper than those developed for a larger character set

The software with small computers usually deals with numerical informatic more naturally than with letters. However, letters should be simple to deal wi on computers large enough to carry a sophisticated high level comput language.

6-26 The balance against the merit of solely numeric codes are the following merits using alpha characters in codes.

A larger character set than the ten decimal is often useful for codes associate with classification since it may lead to fewer symbols. This is particular advantageous if the number of classes to be distinguished by the code greater than 10 and less than 26 since there is then only one letter required place of two numeric digits

Symbols other than the decimal characters are useful as markers in data string Both humans and, to a less extent, computers find single letters or other nor numeric symbols are easier to distinguish than particular sequences of numbe or spaces

The combination of letters and numerics is useful in enabling different fiel (facets or parts) of codes to be distinguishable without the need to add ext tags to each field. Being distinguishable eliminates the need for the fields take up fixed positions relative to one another in documents. If only letters figures are used then this facility requires each field to be of different length or carry a distinguishing tag. Many codes make use of letters partly for this purpos For instance the SfB code has an element facet with a field of two numer characters (NN), a 'form' facet with a field of one alpha character (a) and labour/material facet with one alpha and one numeric character (aN)

Mnemonics using numerical characters would be only of limited value

It is a fact, established by psychological experiments, that human beings ca remember sets of characters containing a mixture of letters and figures bett than sets with the same amount of information expressed purely as letters numbers. For instance British motor registration would require eight decim digits and be more difficult to memorise than the present code with about a equal number of letters and figures.

Binary codes

6-27 By the time information is stored in on-file documents it has usually been reduced a binary code. However, the users of coding systems need not concern themselv

with binary coding except where it has particular advantages. Binary coding is suitable for coding information which can take the form of a yes–no answer to a question. In addition a form of binary coding is sometimes used on mark-sense cards or forms, this being a type of input which eliminates the need for an intermediate document to be produced on a keyboard machine.

Fixed format for code fields

6-28 The definition of fixed field format is here taken to be that each field (e.g. facet) of a code has a particular fixed length and the order in which letters and figures or other symbols appear within the field is invariant. Thus a field AF64 has the same format as BX27 but different format from A236 or AF123.

Most of the codes used in the construction industry including nearly all the quantity surveying codes have this feature.

6-29 Some of the advantages of having codes of this type are as follows:

Missing or added characters within any field on input or output documents are obvious and the provision of check digits is facilitated

Presentation of coded information with fixed format in rows and columns is easy to follow

Fixed predictable format at the detailed level leads to economy of storage and direct access time for on-file documents. Variability of format for larger blocks of coded information can be accessed using an index file which specifies the starting point of each block, but for variable formats at a detailed level may lead to index files being greater than the main file. This, however, is not a reason for excluding variable formats in input documents since conversion to fixed format should be a simple computer operation

Variability of field format makes it more difficult to have variability of the positions of code fields.

6-30 The major disadvantage of having fixed fields is that there may be excessive spare space within the fields if the code structure is to allow for future developments.

Fixed position of code fields

6-31 Many existing codes have a fixed order for the fields within the code. One of these is that developed by Cape Universal Building Products Ltd. as a product code having for each product 7 fixed format fields always arranged in the same order. For example in the code the data sequence 04 L 01 0132 0909 6067 represents Asbestos cement, Fort barge board, 9 ft 6 in. in length, coloured Cumberland Green.

One of the chief advantages would appear to be that simpler routines may be developed for producing and checking input documents and for the interpretation of coded information than if the order of field is varied. Also the use of position as a means of distinguishing code fields may be used as an additional safety factor if it is used in conjunction with other methods of distinguishing the code fields such as the use of tags or to have each type of field of different format.

One possible disadvantage of having a fixed order and number of fields is that there may be excessive redundancy with some of the fields rarely carrying any information. In addition, errors of missing or inserted characters may have repercussions through whole sections of the code unless other checks are incorporated.

Whether on-file documents have fixed field positions or not need not be a concern since computers should find it a simple task to provide the most convenient arrangement. Computers are in any case an efficient tool for converting input documents of fixed or variable format into different arrangements of output.

An illustration of a code for the construction industry

6-32 The Sub-Committee quite rightly felt that the full meaning of the study could or be grasped if an example was given of a code (Appendix H) that had been develope from the study and, in particular, from the criteria the study has thrown up. There a two obvious dangers in this. It might, first, appear that the study team were offeri their own solution to what is essentially a matter for the industry to work on a develop. This is not the case. The code described is put forward by way of illustrati and to show that the application of the criteria can actually result in a practical coc Second, no code can, in the time available, be completely worked out in sufficie detail to demonstrate its applicability to every situation and it might be argued th the examples given have been specially selected. This is true. All that can be said that the code structure was developed from the criteria, and that the code was th applied to the practical and typical examples and was found to work.

6-33 Another point worth clearing at the outset is how people would use the code, an in particular, how much of it they would have to memorise. The answer broadly that the code illustrated here has been devised so that parts that would be in freque use have a mnemonic element, and that items like cost that run through many pa of the code use the same symbols throughout. Even so, many organisations will fi it useful to make one member of staff their main coding link (just as they find useful to have an information officer or librarian). They will also need to use a han book (prepared, no doubt, by the central organisation) which would carry the deta of the code relevant to their work.

6-34 The length of a code depends on the quantity of information the code is to carry and this is inescapable. However, it is possible to ease the difficulty in a number ways. One such way is to have a short code for frequently occurring blocks information and to arrange, when necessary, for the computer to expand this into t full code. Another way is to use prepunched cards bearing a plain language descri tion for manual use. The design of codes is a technical matter that can be tackl satisfactorily only when the manipulations to be carried out and the extent of hum intrusion are known. Sufficient experience has been accumulated for codes to matched to the abilities and performances of groups of users. In well defined circu stances experimental methods are available to test the response of individuals codes and to alternative methods of presentation, and the error rate that resul Clearly such studies are warranted before any general purpose code is adopted the construction industry.

Chapter 7

Criteria

7-1 The purpose of this short chapter is to bring together in one place the criteria for data co-ordination and coding that have emerged from the study and that are discussed in chapters 4, 5 and 6. They have already been given in chapter 1, but are repeated here so as to summarise the arguments so far. Paragraph 7-2 gives the criteria that arise from the needs of the construction industry, the remainder covering practical, commercial, human and computer considerations.

7-2 An information system and its associated code must:

1 Classify information

in sufficient categories for users' needs, and in particular to allow data to be retrieved in order:

to search through data about building types, functional systems, technical solutions, building elements, constructional methods, resources (commodities, materials, occupational groups, equipment)

to select functional system, technical solution, arrangement, construction method and resources with regard to performance, specification, availability and cost

to check compliance with constraints and with regulations

to support feedback within and between projects.

2 Identify and describe resources

to identify uniquely commodities (materials, products and components embodied in construction, contractors' materials, consumable stores), equipment (plant and tools) and occupational groups, in a way that will be convenient for the industry's transactions

to provide the means by which unique identifications can be assigned to commodities etc. This should not involve long delays whilst identifiers are allocated and should be cheap to administer

to produce comprehensive central commodity, contractors' materials, consumable stores and equipment files. This would require appropriate classification, agreed sets of properties for each commodity and resource, and a preferred vocabulary, and the means to achieve them.

3 Describe projects

to describe form by co-ordinates or other methods

to describe the technical solutions by describing work-pieces, identifying or specifying commodities comprising work-pieces, indicating the circumstances in which the work-piece will be completed, locating work-pieces within projects, and stating restraints to be observed

to describe operational methods by identifying the construction method, defining activities, specifying the resources to be employed, depicting the sequencing and timing of the resources, resource scheduling, and progress reports and costings.

4 Foster the development of procedures

to provide categories necessary for data retrieval in ways to suit the needs of various users

to enable documents (drawings, schedules, specifications, bills of quantities, programmes, project proposals, resource schedules), to be arranged in ways convenient to users

to provide the means of co-ordinating conventions evolved for specialist procedures or groups of procedures, a task that includes the development, revision and extension of a preferred vocabulary

to provide the means to prepare suites of related procedures.

5 Support information flow

to identify, for various users, the ways in which information should be structured in order to meet their requirements and to avoid interpretation into another form

to establish a structuring for the documents used in the industry

to identify the categories of information relevant to each document

to provide systems cross-referencing between documents

to establish a framework for accepting, identifying and categorizing standard details, and specification preliminary and preamble clauses

to provide the means of co-ordinating such standardisation

to provide the means of making methods that allow the multiple use of data known and adopted.

Practical considerations

7-3 A system must be capable of implementation in stages.

7-4 A system must be hospitable to separate, but related, sub-systems.

7-5 A system must include the means to co-ordinate its development.

7-6 A system must involve the industry because implementation will affect the whole industry.

Commercial considerations

7-7 A system should not cloud the responsibilities of participants.

7-8 A system must preserve commercial and professional security.

Human factors

7-9 The characteristics of a system should be acceptable to users and adapted to suit their experience and interests. In practice this means prior consultations with users and the provision of adequate training.

Criteria for codes for documents

For input documents

7-10 Accurate production and checking of codes should be easy. This implies that encoding procedures should be appropriate to the skills of the persons involved and that time for referring to code keys should be minimized.

7-11 They should be short for economy of input document production (writing, punching etc.) and computer input time.

7-12 Symbols appropriate to computer input devices should be used.

7-13 Computer time for input codes to be translated into on-file document codes should not be excessive.

Codes for on-file documents

7-14 Codes should be short for economy of storage and internal computer transfer time.

7-15 They should be suitable for the types of file processing required such as retrieval, sorting, producing output in order to minimise processing times.

Codes for output documents

7-16 Codes should be easy to interpret by the user and therefore appropriate to his skills.

7-17 They should be appropriate to the computer output facilities.

Note on the use of the criteria

7-18 It may be helpful to indicate how in practice the criteria can be applied. The most important first step is to establish what an information system or code is intended to do. Those who plan such developments should take as broad a view as they can, bearing in mind that if they take too narrow a view of their purposes, the resulting system or code may have a very restricted future use. Similarly, if they take too isolated a view, the resulting development may be incompatible with other neighbouring developments.

So, first define the rôles the system or code is designed to serve in the terms used in the criteria ("does this system or code classify information? or identify resources? or describe projects? etc.") and then work through the detailed criteria that are appropriate.

Chapter 8

A framework

8-1 In this chapter, a framework for a co-ordinated information system to serve the neec of the building industry is proposed. It has been developed directly out of the criteri adduced from the study and brought together in chapter 7; each criterion is taken i turn to see what it means in terms of a framework.

8-2 Underlying the following recommendations is the belief—reinforced by this study– that it is neither possible, nor necessary, nor desirable to develop a single, com prehensive system of data co-ordination purporting to serve all the functions presentl discharged by the construction industry. It has been argued that the size and diversit of the industry, on the one hand, and the changes occurring within it, on the othe dictate a 'continuous creation' rather than a 'big bang' approach to data co-ordinatior Hence the main recommendation is that a framework should be established t support a number, and possibly a large number of related systems serving the need of the industry. Because of the advantages foreseen, and because of the enthusiasr of individuals, it is natural that progress in some sectors will be quicker than other also it is inevitable that some developments will prosper and others will flounde Hence the framework must be hospitable to systems serving specialised and limite ends, and so structured that the demise of a system does not damage the framewor as a whole.

To classify information

8-3 This criterion embracing the many rôles fulfilled by data retrieval, can be satisfie by a faceted classification, the elements of which are indicated by the informatio requirements of building processes, determined in Chapter 3.

Hence the framework must include a set of *classification categories*.

By themselves classification categories are no more than addresses for data, an it is necessary to co-ordinate data if e.g. valid comparisons are to be made. Hence th framework must include *conventions* for data related to performance and feedbacl

Finally the *classification categories* and the *conventions* will be meaningful only the words used to describe them have exact and unambiguous meanings, hence th need for a *preferred vocabulary*. (This requirement is common to all the followin sections and will not be repeated.)

To identify and describe resources

8-4 Transactions and search procedures in this industry often concern resources– human, commodities, equipment, contractors' materials, consumable stores. Whil many transactions (quotations, orders, delivery etc.) only require resources to b identified, selection requires a degree (perhaps a considerable degree) of specificatio of performance and attributes.

Because projects are composed of commodities, and because each participant t the process maintains commodity records of one kind or another, the case is argue for a *central commodity file* as an important feature of the framework.

Other resources are not common throughout the building process; some are th concern of constructors, some of designers. Hence no immediate provision is mad for identifying or specifying human resources or equipment, although provision i made for *classification categories* for these resources.

Contracting organisations often maintain an abbreviated equipment file, so that the firms' resources can be made available on sites: hence it would be feasible to establish a central equipment file. A human resource file is not possible until the functions of the industry are more directly matched to the attributes, education, training and experience of individuals. The Department of Employment and Productivity maintains records on these lines, and it is suggested that this system is used as a basis for a *classification category* (Appendix F).

To describe projects

8-5 This rôle is at present fulfilled by drawings, specifications and Bills of Quantities, hence the information appropriate to each, and its presentation, should be the subject of a *convention*.

Frequently in Chapter 3, mention was made of the advantage that would be gained from a more rapid updating of project information, as the design progressed. One way to achieve this would be to use computer graphics rather than drawings, techniques that would open the way to more sophisticated design methods. Hence the framework must include *procedures* for computer graphics together with *conventions* for the presentation of data.

To foster the development of procedures

8-6 This criterion will make demands on *classification categories* in order to have data arranged for convenience and to reduce demands on computers, and on *conventions* for the co-ordination of data. Individual procedures, although useful, are less powerful than related suites of procedures dealing with e.g. structural design, or project planning, control and costing. Such suites are likely to be prepared for a group of users because of the rising cost of computer programming and the shortage of computer programmers. Hence the means to promote and co-ordinate these procedures is seen as one part of the framework.

To support information flow

8-7 This criterion, pervading the remainder, will make demands on the *classification categories, conventions,* and *procedures*. It has two other requirements, first to review some of the practices of the industry so that the relationships between the participants more nearly accord with the functions to be discharged, secondly to code in order to compress information, to increase the accuracy of transmission and interpretation and to enable a variety of types of manipulation to be performed.

8-8 Thus far the framework is composed of:

A preferred vocabulary

Classification facets

Conventions

Central commodity files

Procedures

Assigned codes

8-9 This framework would serve the information needs outlined in paras 1-7–1-10. Thus, the client's brief and the form of the building will require conventions for the presentation of production information and a vocabulary from which words used in descriptions are drawn. If form is to be computerised, procedures will be needed, drawing on conventions and vocabulary and making use of codes. A description of resources will use most of the components of the framework: vocabulary, conventions (particularly for performance), classification categories for filing and retrieval. Feedback and data retrieval will draw on all parts of the framework. The procedures

have an importance of their own in that they handle, operate and transmit the data that the data lives and achieves the functions of the industry. There follows a m detailed examination of the constituent members of the framework, and in chapte the problems of establishing the framework are considered.

A preferred vocabulary

8-10 This would be composed of the descriptors used in the other components of framework. A start could be made by including the words used in the classificat categories and in conventions, together with words describing work-pieces (dra from libraries for Bills of Quantities) because these are in general usage. The vocal lary could be extended to include descriptors required for the plain language elem of commodity identifiers, although many could be drawn from libraries for bills quantities. In the course of time it may prove necessary to expand the vocabulary include words used in procedures but this may not be necessary if procedures always confined to groups of specialists.

8-11 Descriptors of *work-pieces* could be derived from the several articulated phr libraries now used for bills of quantities produced by computers. These, being hig faceted, constitute a restricted language and have specification phrases occurr at consistent levels. Libraries should be examined to ensure that they are consist and are capable of being coded. Such libraries could be supplemented by a set standard descriptions, drawn from the basic articulated phrase library, and represent the generality of building work. The coverage and extent of the standard library reviewed at regular intervals, would provide a short code of general applicabi and indicate trends in technical solutions.

Classification

8-12 Classification '. . . putting together things or ideas that are alike, and keeping separ those that are different' is worth doing only when it serves a practical purpose. attempt is made in this Report to discuss classification theory because the team not competent to do so, and readers are referred to the many specialist works on t subject, especially to, 'On Retrieval System Theory', Butterworths, by B. C. Vicke Director of Research ASLIB, to 'The Theory of Classification' a paper prepared B. C. Vickery for the CIB Symposium on Information Flow in Building Process Oslo 1968, and to the second chapter of the study of information systems done ASLIB[32]. This report accepts a faceted and post co-ordinated approach to clas fication.

8-13 When documents (papers, catalogues, books, etc.) refer to one subject only clas fication by an hierarchical system will provide the routines by which documents m be filed and retrieved. In practice, however, data retrieval is normally complicated the fact that documents refer to several subjects, each including many concep The problems of matching an enquiry for recorded information 'about' something the set of descriptors referring to the documents, is then very much more complicat so complicated that none of the many attempts to provide alternative search meth appears to be entirely satisfactory.

8-14 The requirements of an information system to serve the building process are m diverse than the majority of systems of data retrieval, because it must be capable serving, in addition to data retrieval, the many technical and subjective procedu met in design, design realisation and construction. The severity of this problem reduced by the model already adopted and by the growing facility provided computers for rapid access to data and for rapid resortation. The former avoids necessity of using the system of classification to provide information about priorit or sequences (the shelf arrangement problem) since this is given by the routine a its associated flow diagram. The latter makes possible the use, without inconve ience, of a highly faceted classification which can be arranged in the order citation appropriate to a procedure or group of procedures.

8-15 This section proceeds to draw together the classifications required during design, construction and design realisation, as derived in Chapter 3.

Design

8-16 For all designers, and to some extent for contractors, the prime requirement would seem to be categories for filing and retrieving data about performance in its broadest sense. At present the preferred category is *building type,* but building types are essentially collections of functional spaces and systems, each project being composed of a selection of these, determined by the requirements that are to be fulfilled and by local circumstances. Therefore the category *building type* is bound to be less fundamental (although it is clearly of interest to clients and useful for the collection of descriptions of projects) than a category for *functional spaces and systems.* The term functional system is intended to cover e.g. systems for the exclusion of weather, structural systems, circulation systems, waste disposal systems and so on.

8-17 There is clearly a place for a category dealing with *building elements,* and a number of lists already exist. However defined, this category is bound to create ambiguities because some building elements must enter others, (e.g. floors into walls) and elements must be juxtaposed. Some of these could be resolved if a way is found to distinguish whether a reference is to:

A complete member of building element 'A'

An incomplete member of building element 'A'

A member of building element 'B' associated with building element 'A'

Ambiguities remaining are not likely to cause practical difficulties, providing one convention gains universal recognition.

8-18 The information that would be filed under these categories would relate to location, arrangements of buildings, performance requirements and fulfilment, costs and prices, construction methods, technical solution etc.

8-19 It is at least arguable that, for some specialist designers, there would be some merit in a separate category for *technical solutions,* by which is meant the particular solution used to achieve the performance required of a functional system or of a building element. Some consultants might wish to have readier access, for example, to information about blockwork, or flat slab floors, than could be obtained from technical solutions stored under 'functional systems' or 'elements'.

8-20 Designers and the whole building team can be concerned at various times with all classes of goods and will need access to various parts of the whole commodity file. Suppliers may be involved only in certain classes of commodities and therefore need only sections of the file. Certainly within organisations, separation into departments will narrow the interest of individuals, e.g. warehousemen or buyers dealing perhaps only with paints, or hardware, or heating goods, etc. Therefore from a supplier's point of view there would be advantage in sectionalising the classification of commodities according to common commercial grouping. Within these, functional aspects must take precedence over materials because the building team will be looking for solutions to functional problems and should be able to see at a glance what is available; they will be interested in e.g.:

Rainwater goods and accessories	a	Cast iron
	b	Aluminium
	c	Asbestos-cement
	d	. . . etc.

That is, *commodity classification* (Table 3) is seen as a means of grouping together products sold from one source in a way that reflects the functions fulfilled by groups of products.

Construction

8-21 Planning and control centres around activities, the creation of work-pieces which can be specified by:

Boundaries
Indication of circumstances
Resource requirements
Measurement

Each of which will be discussed in turn.

8-22 *Boundaries.* There is, of course, the obvious need to identify projects, areas with projects, buildings within areas and storeys within buildings, and this informatic would go a long way towards solving some of the problems of planners. For ma purposes, however, a finer degree of locational information is required in order define boundaries; for example to determine the limits of the amount of in-si concreting that can be placed, or to check the sequencing of a number of specialis through an area congested with services, or when information is required abo finishings and fittings which are to be put into any room. Here the requirements wou seem to be for *a convention* rather than a formal system of categories because t requirement of each trade within a project might be different. For some elements that is required is a more extended use of the 'The following in . . .' technique; e for structural elements identification of work bounded by main construction joir is probably necessary, whilst for finishing and fixtures room locations would appropriate and so on.

8-23 *Description.* Identification of the type of work demands a plain language descriptic because it must be used for many purposes, including the allocation of work to gan and recording progress. Descriptions can be divided into two levels, the first speci cation, the second, a description of the work-piece.

8-24 *Indication of circumstances* Descriptions do not, however, identify the circumstanc in which construction takes place; they include information about the function of e the structure (some of which make demands upon operatives' knowledge), t likely circumstances surrounding the work, and its position relative to other work. Th information could be given by the *building element* when read against the *locati* in which the work is to take place.

8-25 *Resource requirements.* Identification of the type of work serves a second purpo relating a work-piece to a resource, especially to a declared occupation.

8-26 The relationship between operative occupations and the skills demanded of oper tives is discussed at some length in the report 'Building Operatives' Work' publish by the Building Research Station at the request of the National Joint Council f the Building Industry[18]. This, it will be recalled, although identifying a considerab overlap in the work of trades, found that the conventional division of trades accord reasonably well with the allocation of work within the industry. Some trends we noted, particularly the emergence of groups of operatives who undertake all the wo required to complete some constructional element, ground work, drainage, roofi etc., and the existence of a larger number of operatives able to tackle a fairly narro range of work that would be normally expected to fall within the ambit of one of t main trades, e.g. dry lining.

8-27 The same report also indicated, in outline, how a system of training, which seem well matched to the current demands being made on the industry, might be devis on a modular basis to take account of both these tendencies. Such methods f training have become established in other industries and involve a general trainir common to all entrants to an industry, to be followed by a broadly based traini embracing a general area of work, after which the entrant would be equipped to ca out a range of tasks equivalent to the basic work of one of the existing five ma trades (bricklayer, carpenter, plumber, plasterer, painter and decorator). Suitab operatives proceed to take further modules in order to equip them to carry out t more difficult work within their 'trade', or to tackle other work so that they cou undertake the whole range of work required to complete a functional element. the long run, therefore, it is possible that the present trade structure will be modifi to produce a closer match between occupational titles, defined by a modu

nomenclature, and work that operatives can do, a matter now being discussed by the National Joint Council and by the Construction Industry Training Board. In the meantime, however, the occupational schedule used by the Department of Employment and Productivity (and at present undergoing revision) may provide a basis for an *occupational classification* that will have to be extended to include non-operative occupations. (Appendix E).

8-28 Classification of other resources, e.g. plant, has been discussed in para. 3-76, 77.

8-29 *Measurement.* In the past, measurement has served three purposes, first to identify the quantity of 'work' in a completed product, secondly to indicate the complexity of the work to be done, thirdly to provide a basis for feedback of productivity. Proposals made above will to a large extent remove the need to measure complexity because this should be capable of being inferred from the identification of the type of work together with the circumstances in which the work is taking place. In any case, complexity that can be identified by measurement is only one form of complexity, complexity at the workplace. Other forms of complexity e.g. the arrangement of work leading to a complex organisation with high non-productive time, are likely to have at least as great an effect on productivity and, hence, on costs. It is therefore suggested that the planner, at any rate, would not be much concerned with items of measurement indicating complexity if drawings and Bills of Quantities are adequately cross-referenced. Hence present methods of measurement should be reviewed with the object of relating measurement to the feedback of productivity.

8-30 Productivity can be recorded in one of three main ways. It can be done by the amount of work that a man or a gang can accomplish between e.g. work-breaks, and here it will be noticed that some fairly coarse unit of measurement is assumed e.g. excavate foundations in area 'A', build external wall in position 'B', fix partitioning in areas 'C/D' and so on. Secondly the work on which operatives are engaged may be noted, usually by activity sampling; often observations record two types of information, the first dealing with the task as already described, and the second with a *work element* an operative is performing at the instant he is actually observed e.g. waiting, receiving instructions, transporting, shaping, assembling, making good etc. The third method is by continuous observation in order to determine information which can be used for work-study synthetics, and such studies usually are made for repetitive tasks, probably of short duration, such as might occur in factories for system building. Hence it is likely that the third method of recording productivity will not be greatly used, except by specialised firms, so that any system of data co-ordination need take account of only the first two methods of productivity recording which require only relatively coarse units of measurement together with *work elements*.

8-31 Solely for the purposes of project management it would not seem that much will be gained by standardising the *work element* observed during activity sampling or by work-study, although these methods have their proper place for improving working methods or adjusting gang-balancing. However such standardisation may have a beneficial effect on training and education, and on the general exchange of information about productivity and methods of work. Hence it is proposed that one facet should be allocated to *work elements,* and the considerable experience of the Building Research Station has been used as a basis for those suggested in Appendix F.

8-32 Data co-ordination is likely to play a part in improving the quality of costing information fed back from site, and the two categories already mentioned, (*technical solution* and *commodities*) together with a third category (*construction method*) would seem sufficient to classify information in meaningful ways. Because the first two categories, taken together, go a long way towards defining the constructional method, in the first instance it is thought that the category, *construction method,* need not be specified, the detail being filled in by an individual organisation to meet their specialised requirements. In the long run, there will need to be agreement on the contents of a category for construction methods; contractors will find it increasingly desirable.

Design realisation

8-33 Production information, however generated, should meet the needs and convenie of constructors both with regard to its content and structure, and the latter shoul capable of providing the necessary feedback to designers. That is, the informa produced should be meaningful and usable to estimators, planners, and supervis and structured to match the information flow dictated by site operations and con Estimating, planning and control centres around activities, the creating of w pieces. Hence production information should be grouped accordingly. Work-pie could be grouped by the occupations involved in their construction but it has alre been shown that the construction of work-pieces often entails the employmen several occupations. Therefore it is believed that it is more convenient if work-pie are grouped in sections corresponding to the pattern of sub-contracting in industry, because much work is always sub-contracted. The present arrangemen *work sections* in the Standard Method of Measurement for Building work wo appear as a primary classification and to provide a convenient basis for fur development.

8-34 Boundaries of work-pieces can be indicated by reference to locations with diffe conventions for the principal elements and for different technical solutions. Exc tionally the importance of a work-piece may justify a heading such as, 'The follow in . . .'. More usually, however, a shorter description will be obtained by allocat the quantities related to similar work-pieces to locations: e.g.

Concrete (Spec A) in suspended floor 6 in. thick 454 cu. yd.

Allocation

Block	Storey	1	2	. .	. .	. .	10	Total
1		30	30	30	. .	. .	15	270
2		20	20	18	. .	. .	18	164
3		10	10	0	0	0	0	20

8-35 Allocation of measurement and of materials to locations must be done at the time taking-off quantities, as long as conventional methods of taking-off are employ Hence, the structuring of the taking-off determines the smallest elements into wh work can be grouped and this must restrict the freedom of choice of planners prepr ing construction programmes, even if only insignificantly. In the long run, howe it is likely that taking-off will be by co-ordinate references in which case compu programs can be devised to group together any work appearing within bounda defined by arbitrary planes. So far this work, initiated and being undertaken Douglas Ferry at Southampton University, has been restricted to in-situ concre there would seem no reason to suppose that the principles developed should be applied to construction generally. Descriptions of work-pieces can be divid into two levels, the first to specify, the second to define the work-piece. This type description, which avoids the use of a separate specification, has become establish in recent years and is written into the various libraries for bills of quantities, includ Fletcher and Moore's 'Standard Phraseology' and the libraries developed, for exam by Monk and Dunstone, Herts C C, Notts C C, The Development Group of Charte Surveyors and by the Ministry of Public Building and Works[33].

8-36 The specification element of the description is likely to be affected by the proposa prepare a national standard specification for building work, since this could structured to avoid the repetition of classes common to every project, and to rep only that information essential to the project under consideration. The narrat description might well evolve from the libraries already mentioned, since they sufficiently compatible for further development work to take place.

8-37 It has been argued elsewhere that measurements should be in units against wh site control can be exercised, that is in fairly coarse units of measurement. These different from those given in Bills of Quantities for building work which are intend to fulfill several rôles, e.g. to express the extent of the work to be done, to indicate t amount of waste (e.g. raking, cutting and waste) and to indicate complexity, (e

on sloping surfaces exceeding 15° to the horizontal). The present proposals would not require the expression of waste, because waste necessitated by the design would be included in the list of materials provided (see next paragraphs), whilst complexity would be inferred from the general description, the location, the type of element, and from reference to the drawings. This proposal would constitute a major departure from current practice which could not be implemented without further site trials and the support of the consultative machinery established for this purpose.

8-38 Bills of Quantities as currently prepared are not much used for ordering commodities, because quantities are aggregated (all similar work is lumped together) and because net quantities do not provide sufficient information for ordering, especially for sheet materials. Studies by the Building Research Station have shown that it is possible to state the commodities in terms meaningful to estimators, buyers and merchants. This, of course, increases the cost of taking-off, a cost that might be offset by the more simplified method of measurement recommended in the paragraph above. It should be noted that these measurements are required and are repeated by estimators, by planners and by buyers and that the total cost of the repeated measurement must be considerably greater than that of completing both types of measurement in one operation.

8-39 This grouping of information is:

Work section probably grouped in SMM Trades (to indicate sub-contracting specialists within main trade)

Building element

Description of work-piece 1 Specification 2 Narrative description

Measurement in terms appropriate for planning, control and feedback
Allocated to the appropriate *locations*

Commodities in trade terms
Allocated to the appropriate *locations*.

Given the allocation:

By *work sections*; of interest to contractors and subcontractors

By *building elements*; of interest to designers

By *work section* by *building element* by *location*. Of interest to estimators and planners, because it can be related to networks for planning

By *work-piece* (or groups of work-pieces) by *building element* by *location* to give activities on as fine a scale as the locational allocation permits. Of interest to planner, site controller, progressor and quantity surveyor

By *commodities* by *activities*. Of interest to buyer, site controller, and quantity surveyor

By *location* by *measurement* or by *commodities*. Of interest to site controller and quantity surveyor.

Clearly other arrangements are possible, particularly if the original measurement has been by co-ordinates in which case the information available can be partitioned arbitrarily according to the dictates of the job in hand.

8-40 On the arguments already advanced for project costing greater attention should be paid to preliminaries, and distinction should be made between the commodity and non-commodity elements of each price. An appropriate sub-division would be:

Preliminaries (a) Once-and-for-all, (risk, statutory observance etc.) (b) Those involving an outlay proportional to time (site staff, equipment, rates, telephones etc.)

Site works necessary to but not part of the final project.

'Measured' work arranged by work sections with separate columns
(a) Commodity element (b) Non-commodity element

Preliminary items proportional to tender price, (e.g. insurances)

Feedback of information about productivity and costs to designers could be rela to *building elements,* further classified by *technical solutions,* or to descriptions the *work-pieces*. In either case designers would have to interpret the informat because the actual costs recorded in any project are conditioned by the circumstan of that project. Feedback to constructors would be related to the *activities* selec by the planner (i.e. to groups of work-pieces to which resources were allocat since these take account of the 'this' project circumstances. Since activities unique to projects, constructors will also need to relate the feedback to *techn solutions* and to *work-pieces*.

8-41 Planners and site supervisors all emphasized the benefits that would flow from g cross-referencing between drawings and Bills of Quantities (assuming that specifi tions are embodied in bills of quantities or are related closely to them). Designers f it convenient to classify drawings by *building elements* and we have argued t work-pieces should be classified by *work-sections* and *building elements,* he cross-referencing could be preserved if drawings were scheduled to show *building element* and the *work-section* to which they refer, and also to *locati* shown on the drawings, when this is not apparent, together with correspond references at the work-section or elemental level in the Bills of Quantities. Fina given the use of computers, bills of quantities could be completed by a list of mater (either uniquely identified or specified) arranged to suit the usual organisation materials suppliers.

Classification facets

8-42 To quote Vickery, 'The ultimate test of the value of relations in classification must pragmatic, the good relations will be those that earn their keep in retrieval'. Her although the study has identified a possible rôle for many facets, which could attached to data for filing and data retrieval, it is not imagined that any participan group of participants would find more than a few of them relevant. One task dur implementation would be to match facets to the requirements of different us perhaps making the provision for alternative citation orders. These would indic the relative priority for determining the content of facets, and whom should consulted.

The facets distinguished are discussed in greater detail in Appendix F, in orde indicate their content: they are

Building type Functional space and system Building element Techn solution Commodity classification Construction method Work sec Work element Operative occupation Plant and equipment

Conventions

8-43 Conventions are codification of practice for convenience and better communicati and the industry already uses many conventions. Some are widely observed, example conventions for the measurement of building and civil engineering w some represent good professional practice, for example Codes of Practice for design of reinforced concrete structures, and these form the background aga which the professional practice of specialists are judged; some have comparati limited currency, for example the convention for dimensioning and sizing of re forcing bars, or the British Standard for Drawing Office Practice. Conventions are essential feature of data co-ordination. Examples of conventions noted in Report include location, notations for data input to technical calculations (envir mental, structural, heating and ventilating etc.), measurement and analysis of c data, describing form, for programming and progressing, and for accounting costing.

8-44 Conventions are of three kinds; conventions for feedback and performance data, for procedures and for production information. Each will be briefly outlined in order to indicate the necessity for and the scope of sets of conventions.

Conventions for feedback and performance data

8-45 These conventions are required to indicate physical characteristics of projects. That is, a full citation would indicate a building type functional system or building element together with those aspects of performance that are relevant, and the physical arrangement, the latter being divided into two groups of facets, one group for describing projects in broad terms (the number of buildings and their sizes) and the other for describing individual buildings in more detailed terms.

8-47 Examples might be:

Form of projects:

Height 'x' storeys, 'y' below ground level, in 'z' buildings.
Height 'p' storeys, none below ground level in 'q' buildings etc.

For buildings within projects

area—gross net circulation

ratios—external wall/floor areas glazed/external wall areas internal divisions/floor areas

storey heights—span 3: x(ft or m) for y% net area

Information about performance is needed to make the feedback of data to the categories such as building types functional system, building element, technical solutions more meaningful, e.g. to relate the price of an air-conditioning system to performance requirements. Performance is, in fact, the measure of the extent to which a building meets the requirements demanded from it: some parts of total performance will be capable of numerical expression e.g. temperatures achieved, costs incurred; some will merely be yes/no relationships e.g. does it leak? some will be descriptive e.g. production convenience or demand an arbitrary scale e.g. durability. In all cases, the tendency will be to make feedback and retrieval of information more precise and make possible search routines that commence from the performance required from a system.

8-48 The category will have many sub-facets determined as usage dictates, including facets for restraints which are another aspect of performance.
Examples:

Environmental	temperature humidity air changes ultra-violet light level
Exposure	categories based on degree/days and driving rain index
Maintenance	decoration cycle renewal cycle annual costs, running
Price/cost	estimate tender/quotation final settlement price/cost present value internal rate of return.

Conventions for procedures

8-49 Included in these are technical conventions and conventions for sizing buildings and components, conventions, for the control of tolerances (BS3626:1963), and conventions for jointing all of which are concerned with the co-ordination of building rather than data. Other conventions will be concerned with more specialist aspects of design, and readers are referred to the convention for data input for structural engineering [14] prepared by a committee under the aegis of the Institution of Structural Engineers; clearly similar conventions will be required for other specialisations including topological and geotechnic surveying, environmental engineering, building design, quantity surveying, and for management, including planning, progressing and control.

8-50 In particular a convention will be required for the representation of form, since this will be an essential part of many procedures. The resulting convention is indicated in Appendix H.

Conventions for production information

8-51 The British Standard for Drawing Office Practice for Architects and Builders (BS 119 1953) is limited, in that it considers drawings in isolation from other documen Similarly the report 'Presentation and Format of Bills of Quantities' prepared by t Standardisation Working Party for the Royal Institution of Chartered Surveyors dea only with Bills of Quantities. A more comprehensive approach to this subject illustrated by the report 'Documentation and Planning Methods for Building Desi in Sweden' which summarizes the roles for documentation prepared by worki groups sponsored by the Swedish National Council for Building Research. Th relates drawings, their designation, content, scales, etc., to other documen schedules, specifications, and bills of quantities, and to tendering procedures. Th set of related conventions is much more powerful than are separate conventio adopted by different specialists, and a similar set of conventions would be important step towards rationalising communications in the construction industry.

8-52 Standard specifications and details also co-ordinate building, reduce variety a avoid regenerating information afresh for each project, because the information th include can be drawn into productive information without rearrangement and rei terpretation. (See paragraph 3-106.)

Table 3

Classification of commodities according to common handling practice—commercial grouping.

Heavy goods
Sand aggregates (extractives)
Cements Limes Plasters Additives
Steel: Structural reinforcement sections sheets mesh etc.
Metals: (other than steel) structural sections etc.
Heavy precast units
Walling (all materials) refractories
Damproofing expansion and contraction joint fillers tanking etc.
Drainage Castings
External works Landscaping fencing roads and paths
Fixtures and fittings
Timber: Structural Boarding
Doors (any material) and gear
Windows (any material) and gear
Cupboards and fittings (any material)
Roofing and similar claddings
Fully supported coverings (felts, mastics, etc.) underlays
Self supporting sheets (rigid formed)
Lapped units (tiles slates shingles)
Accessories: Ridge Hip coverings fastenings
Claddings: supported or self supporting weatherproof and/or decorative
Rainwater goods and accessories
Finishes and insulation
Floor finishes: tiles sheet formless coatings (mastics etc)
Wall finishes: tiles applied coatings

Ceiling finishes: tiles decorative acoustic cornices coves ornaments

Wallboards Panels partitions plasterboard

Insulating materials: Boards panels felts foils matting wrapping

Builder fixed soft furnishings

Adhesives and jointing materials generally: putty strip mastics

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Hardware

Tools (all types)

Fixings and fastenings: nails screws bolts etc.

Door and window: furniture locks

Brassfoundry generally

Metal sheet: flexible semi-flex and rigid perforated or plain

Metal sections trims etc.

Plastics and rubber: sheets sections etc.

Ropes cords etc. any material

Wires and wire goods: other than fencing and reinf.

Plumbing and sanitary

Sheet materials

Tubes and fittings (any material)

Cisterns tanks cylinders

Sanitary ware baths basins closets sinks etc.

Plumbers brassware and sundries

Heating and ventilation

Boilers fires heaters grates burners (all fuels)

Ancillary equipment: radiators pumps valves controls etc.

Ventilation equipment: ducts grilles ventilators etc.

Flues chimneys terminals

Electrical

Equipment & control gear

Cables & conductors

Cable supports: conduits trunking trays etc.

Fittings and accessories

Sundries

Glass and decorating materials

Glass

Paints and varnishes etc.

Painters requisites

Wallpapers & similar

Civil engineering

Construction equipment (plant etc.)

Site huts scaffolding etc. (preliminaries)

Timberwork: formwork shoring Jetties

Piling

Roads and pavings

Sewers drains & pipelines

Railway trackwork

8-53 Conventions for measurement to be revised so that these are related to the inform tion that can be fed back by progress reports and by activity sampling, together w the need to agree conventions for grouping production information by locatio appropriate to work on site.

A central commodity file

8-54 Considerable emphasis has been laid already on the need, that runs throughout t building process, for a central commodity file (see paragraph 3-140). It will recalled that this file can take many forms, the essential feature being prior agreeme as to the content and presentation of product information. Initially, as agreement reached, manufacturers and merchants can prepare their product information compatible ways, and subsequently this could be grouped in catalogues correspor ing to the present arrangement of the supply industry and to the interests of design in particular (Table 3). Eventually this information can be held in computer d banks and, when data links are commonly available, it would probably be advan geous to have a central commodity file, or files, to which users could have acce Table 1 gives, albeit in a tentative form, the sort of information that such a file sho ultimately hold. Of course it would not be necessary to provide all the informat initially.

In summary, the file would have, as information common to all users:

Identification
Composition, method of manufacture
Properties (performance)
Shape, dimensions, weight
Application
Distribution
Prices, costs and accounting

8-55 To this would be added information that would be private to the supplier, as follo

Production information
Stockholding information
Accounting information

8-56 For any particular project, the supplier would also need to add, again for private u

Customer
Account number and credit rating
Stockyard details

8-57 The following, also relating to a particular project, would be available for the supp and the customer:

Identity of project
Site
Limitation on access/delivery
Area within project
Item quantity list
Activity number
Earliest delivery
Latest delivery

8-58 Clearly preparation of a general commodity file would be no mean task, yet it task that is already undertaken, and in a way that inevitably leads to duplication a to difficulty in locating information when it is required. The preparation of a cen commodity file could be undertaken in two stages, the identification of commodi

and the collection of information relevant to each commodity. Whilst different users will have different requirements for information all users, operatives included, need to be able to identify commodities. Because of this, identification will be discussed in some detail.

8-59 Considerable attention has been paid to the problem of identifying commodities and a common pattern is emerging, entailing the use of four types of information in a commodity heading: firstly a code for origin, secondly a non-significant number, thirdly a classification of the commodity, and fourthly a brief verbal description which might include some important characteristics such as size or capacity.

8-60 The first two of these could follow the pattern adopted by the Standard Book Numbering System, in which there are two fields; the first to identify the publisher, the second the book. Thus the first field would indicate a manufacturer or merchant and this could be by the GIRO code. The second field would be a non-significant number allotted by a manufacturer, merchant, or for commodities satisfying a more general specification—a British Standards Specification for example—by the British Standards Institution. Commodities fulfilling an industry standard—e.g. commodities such as the 'Public Building Frame' or standard bridge beams that can be obtained from several sources although not the subject of a British Standard—should be given a number by some organisation yet to be nominated. It is suggested that the numbers allotted to commodities fulfilling national or industrial standards should be clearly distinguishable from those given by manufacturers and merchants, perhaps by having a first character of N for national or I for industry standards.

8-61 A plain language description is probably necessary to complete the identifier in order to avoid errors and to give greater measure of comprehensibility. The first requirement would be an agreed terminology so that precision is obtained and local idiom suppressed, and the second some agreement as to structure, probably a faceted language, along the lines of those developed for libraries for descriptions of Bills of Quantities. Information already given would be sufficient for most purposes, but sometimes it would be necessary to add information drawn from the specification or performance sections of the commodity file, for instance Class A or B in the case of engineering bricks.

8-62 The various sectors of manufacturing and supply industries could make a start in the direction of a central commodity file by preparing commodity information in compatible ways, a task that would require determining just what information about a commodity was of interest to all users and the most useful way of presenting it, including details that could be copied directly on to production drawings. This would considerably simplify the subsequent collection and codification of central commodity files. It is possible that central commodity files should be prepared initially for commodities with a high technical content, mechanical engineering equipment, for example, for which users wish to ask precise questions about pump characteristics, bolt hole spacings etc.

8-63 A possible code for commodity identifiers and for a central commodity file is indicated in Appendix H.

Procedures

8-64 It will be recalled that the functions of the industry have been shown to be discharged by the execution of procedures in which information is received, processed and put out (see Chapter 2). Much of the work of the study has centred around the development of outline procedures and it is believed that suites of related procedures could make an important contribution to the efficiency of the industry.

8-65 For example, procedures have already been developed for the preparation of Bills of Quantities by computers, and steps are in hand to provide facilities useful to contractors for estimating, planning and site management. Also initiatives taken by the Working Party on Computer Programs in Structural Engineering (a sister com-

mittee to the Committee on Coding and Data Co-ordination) has resulted in a revie of structural engineering programs and a provisional specification for a suite programs capable of dealing with commonly occurring structural engineeri problems. The possibility of this suite, called GENESYS*, has aroused considerab international interest and support. Similar initiatives are occurring in other secto architectural design, environmental engineering, and contracting and sub-contractin The National Computing Centre, the Ministry of Technology and computer manufa turers are all anxious to contribute to this work because a proliferation of procedur and programs is recognised as an impediment to computer application and waste of skilled resources.

8-66 In many respects these procedures would be an extension of Codes of Practic now a recognised part of the industry's information. Whilst they would make ava able to all the results of research and accelerate the adoption of new techniques a computer application, they would not reduce the advantage to be obtained by individual practitioner who prepared advanced procedures to meet specific nee However, in the long run, the sheer cost of writing suites of computer programs likely to dictate the need for agreed procedures; whether dealing with technical management matters, and it is expected that these are likely to become a cent feature of the industry's work.

Assigned codes

8-67 Not all data co-ordination requires a universal code; some aspects require no co some can make use of arbitrary ad hoc codes, some can employ codes of limit applicability, some will benefit from a universal code[34]. Here we are concerned or to distinguish those aspects for which a universal code is essential, because the oth present no real difficulties.

8-68 When data of a given type is passed between participants coding can be expect to confer advantages because both the generators and users of the information c adopt common procedures and present data in a way that is immediately useful recipients. Here it must be noted that a common code is not essential, providing t data is properly structured and the terms used have precise meanings, because rec ients can translate the documents they receive. What is essential is that informati is grouped so that it can be rearranged to suit the needs of users, and that t information can be interpreted unambiguously.

8-69 Hence, in the first instance at least, there might be merit in limiting the use of industry code to those procedures that are industry-wide, because it is probable th codes designed to serve specific rather than general purposes will be more effici and compact.

8-70 Designers, having completed outline solutions to problems, expend much effort select commodities with the required performance, a procedure that may requ search patterns initiated along different lines e.g.:

> Is there a commodity with a performance of A, B, C . . . at a price not grea than D?
>
> Does commodity type E meet the general performance requirements of buildi type F?
>
> What are the sources and availability of commodity type E?
>
> What commodities are compatible with commodity type E? and so on.

Hence, much of the advantages of a central commodity file will stem from a code facilitate these manipulations. This implies that the industry code should include *classification categories,* the conventions for *feedback and performance data,* a the identifiers of the *central commodity file*. Some aspects of the file need not coded, for example production information of interest to a group of manufacturer

8-71 The other type of information, central to design, is concerned with the *form*

* See Glossary

projects and any industry code must be capable of accommodating *graphic data,* because this is the essential vehicle for design and production information.

8-72 The case for a code to accommodate design procedures is not as strong, because most procedures are specific to groups of specialists, and the manipulations central to some procedures may be made more economic if codes devised for the purpose are employed. In the long term, however, the possibility of linking together suites of programs to optimise designs might make more necessary the use of universal codes for procedures, although the cost of using compilers to interpret from one code to another may be more than offset by the economy obtained from using codes closely matched to the individual suites of procedures.

8-73 Constructors draw on production information in order to estimate, plan, execute, control and cost work on site. Hence efficiency will be increased and costs reduced, if production information is made more directly relevant by adopting the proposals of this report aimed at standardising the content of the various documents, at improving the grouping of information, and at improving cross-referencing. However these presuppose the continuing use of hard copy, i.e. drawings and bills of quantities, and, consequently, extraction of data. Further advantages would be obtained if the data included in bills of quantities is made available on tape or by direct transmission on data links, since this could be merged with estimating and planning procedures. Hence an industry code should embrace the descriptions and format of Bills of Quantities. Descriptions of or the identity of commodities would be drawn from the central commodity file, if such existed. References to conditions of contract, to the national specification for building work or to standard details, could all generate the complete information when this is required.

8-74 Transactions with suppliers would be assisted by a code for the identity of commodities together with the additional information listed earlier. This places few additional requirements for coding other than those already made by the central commodity file to which contractors would also refer when seeking commodities to meet specification and performance requirements.

8-75 Procedures specific to constructors (estimating, planning, costing etc.) are analogous to those used by designers in that there is no necessary requirement that codes for them should be drawn from an industry code. Indeed some sections may be more efficient if directly related to codes serving other industries e.g. payroll or tax routines.

8-76 Hence a construction industry code should initially embrace

Classification categories

Conventions for feedback and performance data

Conventions and procedures for the presentation of graphic data

The central commodity file

Bills of Quantities.

8-77 The code described in Appendix H has been developed as an example to show how the criteria for codes, the needs of users and the requirement to be suitable for manual and computer methods can all be met. It is believed that the code can be adapted to meet the several requirements listed above. It will be noted that the code has a mixed alpha/numeric form with a fixed format in order to meet the requirement to be reasonably convenient for manual use.

Chapter 9

Implementation

9-1 Rising costs, especially of labour, and the extension of computer working are like to bring about a measure of data co-ordination and coding, whether or not mo decisive action is taken. However, although piecemeal implementation is attracti on many counts, and would not disturb the existing arrangements of the indust much would be lost if a concerted attack is not made. In any case, the developme of the framework on the lines indicated in this report will take several years (Appenc G), and can be effected only with the co-operation of all concerned. During this tir the power of computers will increase and there is every indication that comput application will become relatively cheaper and more widely available. Only starting now, will the industry be ready to take advantage of these computer faciliti as they develop.

9-2 Implementation would appear to be justified by savings in cost, quite apart from t benefits stemming from the use of more advanced techniques, from optimised desig from the avoidance of abortive work, from better management information designers, constructors and suppliers, all of which are likely to be important. Econor will arise from the information about commodities and past projects that should available to designers—it is believed that between 10 per cent and 20 per cent design effort is spent in searching for information. Preparation of production infc mation will benefit from the use of standard specifications, details and descriptior which will be able to be merged with documents, thus saving time in drafting a reducing the amount of written material. Savings should accrue to main and su contractors, because estimators will be relieved of the chore of regenerating produ tion information, and buying procedures will be streamlined. Manufacturers a merchants should be able to effect considerable savings by adopting computeris procedures for handling quotations, orders, invoices and accounts. These savin are, of course, difficult to quantify, because there are so many unknown factors. however, attention is concentrated on new works, and if savings accruing to smal firms are entirely neglected, it would seem that the saving to the industry could not less than £30m per year—a figure that is more than thirty times greater than t estimated annual cost of implementation.

9-3 This argues that data co-ordination and coding should be pursued energetical rather than allowed to happen. Just what would be involved? What tasks would ha to be discharged? These fall into two groups; the development of the framework a the promotion and co-ordination of data co-ordinating and coding.

Development of the framework

The preferred vocabulary

9-4 A contract for the development of a vocabulary for the building industry is beir placed by CIRIA with two classificationists at the Brixton School of Building and t North West Polytechnic. The outcome of this contract, due in 1970, when merg with a library of descriptions for Bills of Quantities could form the initial preferr vocabulary. Subsequently, the vocabulary would have to be amended as new co ventions and procedures are derived.

Classification facets and conventions

9-5 Because these affect more than one group of practitioners it is probable that th should be prepared by full-time specialists advised by industry-based workir parties. In any case the results should be widely circulated for comment, as a British Standards and Codes of Practice.

9-6 The tasks first to be undertaken should be the derivation of:

Facet for functional space and system

Facet for technical solution

Convention for feedback and performance

Conventions for computer graphics

Revision of conventions for measurement

Conventions for documentation

Conventions for contractors costing and accounting systems

Preparation of standard specification and standard details.

A central commodity file

9-7 As has been explained this task may be divided into two stages; establishing a system to identify commodities, and preparing a comprehensive central commodity file.

9-8 Identification of commodities would require an organisation to allocate reference numbers to suppliers (but not if GIRO references are used), and to identify and number national and industry standard commodities. This organisation could also undertake the compilation and publication of the catalogues defined by the classifier (8-20); a task that would enable it to derive and apply standards for the content and presentation of manufacturers' and suppliers' information, and thus pave the way for a central commodity file on the computer.

9-9 Although full benefit could not be derived from a central commodity file until an adequate computer network exists, the rate of expansion of computer facilities suggests that a start should be made in the near future if the industry is to be fully ready when this network is established. The first and major step would be to determine the information appropriate to each commodity, including the aspects of performance that should be included in the file. Given agreement on these issues, the commodity file could proceed when warranted by the availability of a computer network.

9-10 Clearly the preparation of the initial files would be no mean task. Such evidence as there is suggests that it would cost £40–50 per item to prepare a record for each commodity (excluding commodities that differ only in e.g. size or colour), and to service the central file. There are no reliable estimates of the number of commodities in the industry, but the National Federation of Building and Plumbers' Merchants has estimated that 100 000 commodities would be sufficient for the generality of commodities used for building and civil engineering purposes. Hence the preparation of an initial central commodity file for building and civil engineering commodities might cost £5M or roughly 1400 man-years of effort. At first sight this seems large, but it is small when compared with the commodities consumed by the building industry (£1200M pa) and with the number engaged in preparing and seeking data about commodities.

9-11 Once prepared the commodity file would have to be updated to take account of new commodities, and those no longer available. The assumed availability of a computer network would greatly simplify this task, because information fed into the network by manufacturers and suppliers would be immediately available to all users. That is, it is expected that any central organisation would monitor additions and deletions to the file and agree the format of data for new commodities, and amendments to format already agreed. In this way operational costs would be kept within bounds, and manufacturers and suppliers would not be faced with delays whilst their data was being processed.

Procedures

9-12 The effort to prepare suites of procedures and related computer programs will be considerable, in particular if provision is made for graphic displays, for optimisation,

and for man/machine interaction. Since the number of systems analysts and p grammers is limited, and the construction industry cannot expect to obtain more th its fair share, it is suggested that this problem must be discussed with the Ministry Technology, with the National Computing Centre, and with computer manuf turers to determine the number of systems analysts and programmers that could reasonably allocated to the construction industry. These would be deployed reflect the interest of different sectors of the industry, and their willingness to ma use of the developed procedures. This does not imply, of course, that procedu should be developed by a central organisation. Initiative is likely to arise in ma places – universities, the computer companies, consultants, firms and trade orga sations – and should be supported when the outcome has promise and is likely command the acceptance of users. The task falling to any central organisation is encourage, support and co-ordinate the development of procedures and to prom their use.

Assigned codes

9-13 Priorities for coding have already been indicated. The task of deriving codes wo not seem considerable, providing the data is co-ordinated and its structure is broa in accordance with the framework proposed. Again, once the initial codes have be derived, any central organisation would have to advise those adopting the cod and perhaps co-ordinate the adoption of codes for related purposes.

The organisation necessary

9-14 Although these tasks could be allocated amongst the many representative bod in the industry, it is unlikely that this would lead to orderly and vigorous progr Each task is related to the others in a way that indicates a degree of central purp and co-ordination that can be achieved only by a single organisation charged wi the task of promoting data co-ordination in the industry. Its functions would be

Advise: An essential rôle if the intention to encourage independent action by gro of practitioners is to be realised. Advice would include making available informat about work already undertaken or in hand, bringing together parties undertak complementary developments, and discovering and making available related w undertaken elsewhere, including universities, commercial concerns, and ot industries.

Collate: This task, implicit in the advisory rôle, would entail collection of informat about data co-ordination and coding likely to be useful to ordinary practition that is, those who are not intending to undertake independent development as w as to development groups. This rôle would complement the wider rôle of the Natio Computing Centre by concentrating on the aspects of data co-ordination computer usage central to the interests of the construction industry.

Co-ordinate: Encouragement of independent action must be matched by co-ordi tion if such actions are to be complementary so that they can be merged w further developed. This crucial function can be discharged only if the organisat responsible has some measure of autonomy, and the problems of providing a bala between democratic representation on the one hand, and of ensuring suffic autonomy for effective action on the other, will have to be resolved, possibly al the lines followed when CITB was established.

Undertake the tasks essential to the development of data co-ordination:

The preferred vocabulary
supervising the preparation of the initial vocabulary;
subsequently extending and updating.

Classification facets and conventions.
Implementation and extension as dictated by need, and with the adv of industry-based working parties.

A central commodity file.
Supervising the allocation of identifiers, determining the content and presentation of catalogues; subsequently preparing a central commodity file and monitoring additions to and deletions from it.

Promote the use of data co-ordination and coding, including procedures. This would involve the whole gamut of promotion including education, lectures, short courses, and publicity.

Survey research and development requirements and initiate work essential to the furtherance of data co-ordination and coding in the construction industry. This function would have to be married into the framework now provided by the Construction Research Advisory Council.

9-15 The team was not asked to recommend which, if any, of the existing bodies in the industry might be appropriate for this task, because this is the prerogative of the Sub-Committee. In order to assist them an estimate was made of the cost of implemention (Appendix G). This is, of course, no more than a cock-shy, because much will depend on the tempo of development which will itself turn on the enthusiasm with which the industry adopts data co-ordination, and on the funds available.

Chapter 10

Recommendations

The framework

10-1 In this chapter, the specific recommendations made in chapters 8 and 9 are broug together for easy reference.

10-2 A framework for an information system is recommended, to consist of:

A preferred vocabulary that would consist of the descriptors used in other parts the framework.

Classification categories (see Appendix G) to allow information to be filed, retriev and sorted in ways useful to the industry. The following categories are recommende

- Building type
- Functional space and system
- Building element
- Technical solution
- Commodity
- Construction method
- Work section
- Work element
- Operative occupation
- Plant and equipment.

Conventions for feedback and performance data, for procedures and for productic information.

A central commodity file in which information about materials, products and con ponents would be systematically made available.

Procedures developed preferably in related suites, for formalising many of th functions performed in the building process as a prelude to the wider use of computer

Codes to make the transmission of information more reliable and more economica

Implementation

10-3 Implementation will require both central and sectional activity, the sectional activit being centrally co-ordinated. Sectional activity would be concerned with the develop ment of procedures, and with some aspects of coding.

10-4 A central organisation is recommended to advise on sectional action and to co ordinate it, to collate information on implementation and to supervise the vocabulary the classification facets, the conventions and the commodity file, and generally t promote the use of data co-ordination and the identification of research and develop ment needs.

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32 'A study of information systems relating to the construction industry.' Report Aslib Consultancy Service for BRS 1968. GP.

33 'The preparation of bills of quantities with aid of computers: some case studi C. H. Farrar and R. F. W. Malthouse. To be published by MPBW.

34 'Design and information flow'. A. Gordon. Paper presented at the CIB Confere Oslo* 1968.

***CIB Conference**

The International Council for Building Research, Studies and Documentation (CIB) organised a conference 'In mation flow in the building process—classification and coding for computer use' held in Oslo in June, 1968. papers for this conference provide a valuable source of reference.

Acknowledgements

It will be apparent to those who read this report that although the work of the study team itself has made by far the biggest contribution to the report, the report has benefited from a great deal of earlier work on communications in the building industry. Indeed present interest in the subject stems in part from earlier pioneer efforts in a number of countries, as will be seen from the list of references. The thinking that has gone into the report on the subject of classification has been heavily influenced by the views of Mr. B. C. Vickery and his colleagues in Aslib, to whom acknowledgement is due. The study has also drawn on past work at the Station, in particular the studies listed in the references.

It cannot be too strongly emphasised that although the report appears under the names of two authors, the whole study has been a team effort, and the authors wish to pay tribute to the work of their colleagues. The team members and the sectors they studied are listed in Appendix B and Appendix D. Chapter 6 of this report and Appendix H are the work of Mr. D. Whiteside.

The authors also wish to express their appreciation of the support they have had from the Chairman and the Sub-Committee during the course of the study, and are grateful for the discussions that they have had with them. The study team has also had many useful discussions with a large number of firms and individuals: their willing and detailed help in checking the feasibility of the routine and information schedules and in many other ways is gratefully acknowledged; without it the study could not have been carried through.

Appendix A

Ministry of Public Building and Works

Sub-Committee on Coding and Data Co-ordination

Chairman	
A. J. Gordon, OBE, Dip Arch, FRIBA	Alex Gordon and Partners
Members	
W. T. F. Austin, BSc, CEng, FICE, MIStructE, MInstHE, MASCE	Freeman Fox and Partners
B. K. Cheele	M. P. Harris & Co. Ltd., Builders' Merchants
P. A. Denison	Cape Universal Building Products, Building Materi and Component Manufacturers
P. H. Dunstone, TD, FRICS	Monk and Dunstone
L. Fletcher, FRICS	Leonard Fletcher and Partners, Quantity Surveyors
W. G. Howell, DFC, MA(Cantab), AADipl(Hons), FRIBA	Howell, Killick, Partridge and Amis
W. M. Laing	Nathaniel Grieve & Co.
P. F. Miller, AIOB	John Laing Construction Co. Ltd.
D. M. Parkyn, PhD, BSc	National Computing Centre
I. Tomlin, FIBE, AIOB	Howard Farrow Ltd.
J. Whittle, SPDip, FRIBA, MTPI	Greater London Council Deputy Architect
Assessors	
N. E. Higgitt, FRICS	Directorate General of Production, Ministry of Publi Building and Works
W. J. Reiners, BSc	Director General of Research and Development, Ministr of Public Building and Works
D. Campbell, BL	Directorate of Research and Information—in attendanc from main Computer Committee
Secretaries	
B. C. Edgill, ARICS, Technical Secretary	Directorate General of Research and Development Ministry of Public Building and Works
C. Caudwell, Secretary	Directorate General of Research and Development Ministry of Public Building and Works

Appendix B

The Study Team

Building Research Station Staff

Not all those listed were full time on the study; some were in the team for specific short-term studies.

K. Alsop BSc, AInstP
D. Bishop ARICS, MICE
I. Britten BSc
C. D. Daltry
C. H. Farrar ARICS
B. Fine BSc, ARCS
Miss M. K. Gray
Miss C. Handford
C. R. Honey BArch, ARIBA, FNZIA
H. J. Hussey
D. J. Hutchings BA
R. E. Jeanes BSc
R. C. Marriott BA
J. I'a Nelson BA(Eng)
C. Robinson
A. Russell BSc
A. J. Sluce BSc
R. F. Stevens MEng, AMIStructE, MICE
D. Whiteside BSc
E. W. F. Warrington BA

With Mr. Bishop's appointment as Director of Quantity Surveying Development and Chief Quantity Surveyor, MPBW as from 1st January 1968, Mr. K. Alsop led the team, with Mr. Bishop retaining a close interest in the work in a consultant rôle, and sharing the drafting of the final report.

Non BRS Staff

C. A. P. Crooke ARIBA	Directorate General of Research & Development MPBW
A. G. Foster MIHVE	Heating and Ventilating Research Association
H. P. Johnston DFH(Hons), CEng,.MIEE	Directorate General of Research & Development MPBW
R. F. W. Malthouse ARICS	Directorate General of Research & Development MPBW
L. Monument MIStructE	Directorate General of Production MPBW
J. Webster	Heating and Ventilating Research Association

Contracts for particular sections of work for the study were placed with:

Aslib
D. Brewster
Peter Burberry
CFD Partnership
Hutton & Rostron
McLennan and Partners
Robert Matthew, Johnson-Marshall and Partners
Watford Computer Centre

Terms of Reference

To study the present characteristics and probable development of the information used in the design and execution of construction work; to determine the criteria for a coding system which would enable computer-processed information to be used more effectively, both within individual firms and offices and in communication between them, thereby leading to greater efficiency and economy; and to make recommendations.

Appendix C

Verbs for describing procedures

Determinate procedures

Many of the preferred verbs in this list are given rigid definition in BS 4058 and have n precise synonyms.

	BS 4058 Symbol Number	Definition	Synonym
Input			
Enquire	12	to ask for specific information from a located source.	request, ask for
Measure	12	to quantify or codify a characteristic; to note a statistic.	count, time, record, dimension, quanti
Read	12	to take in information in a given order.	
Process			
Extract	8	to scan a source and remove data having a specified characteristic.	abstract, retrieve
Sort	10	to scan a source and arrange in order according to specific criteria.	
Merge	7	to scan and combine two or more sets of data into one.	
Collate	9	to scan, merge and extract into new divisions.	
Classify	1	to allocate to predetermined divisions.	index, label, rank, group, arrange
Calculate	1	to perform a mathematical/logical operation	add, subtract, multiply, divide
Decide	2	to choose between alternatives on the basis of specified criteria.	
Translate	1	to convert from one form to another.	
Record	1	to store the result of a process (or an input) symbolically.	file, list
Draw	1	to store the result of a process (or an input) iconically.	
Display	24	to present a result in temporary visual form.	show, present
Transmit			
Report	12	to write/speak or otherwise pass information.	tell, inform, print out, notify
Submit	12	to write/speak or otherwise pass information for approval within another function.	transfer
Order	12	to write/speak or otherwise pass an instruction with authority.	instruct, specify

Non-determinate

	Definition	Synonym
eek	to decide where information might be found and to search for it.	to search for, call for, investigate, scrutinise
iscover	to acquire information without search, recognising it as useful	hit upon, realise, recognise, perceive, sense
bserve	to note a non-measurable characteristic (e.g. colour, texture).	
iscuss	to exchange information.	exchange views, confer with
ppraise	to assign a value on a subjective scale (the objective equivalent is measure).	gauge, set a value on, evaluate, assess
ssume	to adopt a hypothesis; to postulate	suppose, conjecture, to adopt a possible solution for trial
stimate	to calculate using some assumed values (the objective equivalent is calculate).	to compute, reckon, quantify using some values which have been appraised
nterpret	to represent in a new form by a process involving judgment of intent (the objective equivalent is translate).	clarify, explain, make intellifible, construe, understand.
nalyse	to determine component parts and divide accordingly.	sub-divide, break down
ynthesise	to build up a solution from unrelated component parts.	combine, build up, compound, compile
ummarise	to decide upon and extract information of greatest value or significance	abbreviate, abridge, condense, outline
udge	to choose between alternatives on the basis of disparate criteria (the objective equivalent is decide).	discriminate, arbitrate, decide on the basis of opinion rather than fact
elect	to scan data and remove items on the basis of disparate or ill-defined criteria (the objective equivalent is extract).	choose, approve, recommend after judging subjectively

Appendix D

Sectional reports

The following sectional reports were prepared to provide the basis for the model c the flow of information presented in the main report. Each is self-contained and wi be published as a Building Research Station Current Paper early in 1969.

A study of the flow of information in architectural design

C. R. Honey, FNZIA, ARIBA (of BRS)

The ascertaining of briefs, development of designs and completion of productio information for single projects where building is predominant (rather than civ or plant engineering) are discussed.

Procedures prepared

- The basic pattern of design procedures
- Procedures for the outline design of layouts
- Rainwater drainage
- Environmental design
- Roads and paths
- Floor finishes
- Roof finishes
- Partitions
- Suspended ceilings
- Windows

A study of the flow of information on mechanical engineering services

A. G. Foster, MIHVE, J. Webster (both of HVRA), H. P. Johnston, MIEE (of MPBW

The design and programming of mechanical engineering services and labour an materials estimating are covered in this section.

Procedures prepared

- System design, analysis and development of outline scheme
- Heat loss calculation including final elements
- Mechanical ventilation and warm air heating design
- Air conditioning design
- Hot and cold water services design including tanks and calorifiers
- Duct sizing including filters and fan
- Pipe sizing including boilers and pumps
- Plant room design and layout
- Controls design
- Planning of installation processes
- Programming
- Labour cost estimating controlling analysing
- Material cost estimating controlling analysing
- Heating and ventilation services (general)

A study of the flow of information in structural engineering design

R. F. Stevens MEng, AMIStructE, MICE (of BRS), L. Monument AMIStruct (of MPBW)

The flow of information in the process of construction as it concerns the Structura Engineer has been considered in terms of the organisation of the design team, th work carried out by the Structural Engineer and the information required for th effective performance of the work. The computer programs held by the Institute o Structural Engineers are reviewed.

Procedures prepared

Structural feasibility design
Structural sketch design
Production of structural working drawings
Structural supervision during construction

A study of the flow of information in electrical distribution design
H. P. Johnston, MIEE (of MPBW)
Electrical design and, in less detail, electrical contracting is covered in this section showing some common links to the Heating and Ventilating section.

Procedures prepared

System design, analysis and development of outline scheme
Artificial lighting and small power design
Power requirements and internal distribution design
Power supply, external distribution and sub-station design
Communications, alarms and control systems design
Lightning protection and earthing design
Planning of installation processes
Programming of installation processes
Labour cost estimating controlling analysing
Material cost estimating controlling analysing

A study of the flow of information in quantity surveying, product manufacture and merchanting
C. H. Farrar, ARICS (of BRS), R. F. W. Malthouse, ARICS (of MPBW)
Information flow in the following activities is considered:
Quantity surveying: Cost control, Bills of Quantities (i.e. procurement tools), post contract monetary control.
Manufacturing/merchanting: Materials and products, supplied when and where required.

Procedures prepared

Cost planning
Cost checking (during design stage)
Production of Bills of Quantities
— Processing dimensions
— Preparation of operational bills
Cost analysis of tender
Valuation for interim payments
Preparation of variation (final) account
Cost analysis of contract

A study of information systems relating to the construction industry
Alan Gilchrist, ALA, Kathleen Gaster, ALA (both of Aslib)
Sixteen schemes devised for information and data handling were surveyed and examined with regard to the classification and coding employed by each.

Schemes surveyed

Library based schemes

UDC
SfB
Miss Plowden's classification
Systems using co-ordinating indexing
Other systems

Commodity coding

NATO/DCA

Management information system

Cape Universal Products Ltd

Manufacturer/designer liaison

Hertfordshire County Council/Crittal Manufacturing Co Ltd

CFD/Medway Building Ltd

Bill of quantity production

Fletcher and Moore
Monk and Dunstone
Hertfordshire County Council
Greater London Council
Ministry of Public Building and Works
Development group of chartered quantity surveyors

Systems of wider scope

West Sussex County Council
CLASP (Consortium of Local Authorities Special Programme — Nottinghamshire County Council)
CBC (Co-ordinated Building Communication)

Instructions to operatives
J. I'a Nelson, BA (of BRS)
Site operations, covering both the management and execution of building w
which are examined for information needs.

Procedures prepared

Site control
Operation control
Work-piece testing

Contractors' management
J. Britten BSc
Deals with several aspects of management within building firms

Procedures prepared

Project selection
Appraisal of alternative working methods
Outline planning and cost estimating
Appraisal of tenders
Detailed planning
Multi-project resource scheduling
Personnel selection
Bonus targeting
Materials utilisation and cost reporting
Progress reporting and cost control

Appendix E

Occupational classification for operatives

prepared by J. I'a Nelson BA

E-1 Although in the long run occupational classifications should be developed for all those engaged in construction including specialist designers, planners, managers etc., it is probable that more would be gained immediately by classifying operative occupations.

E-2 It was thought that the Standard Method of Measurement for Building Work might provide a possible system, if section and sub-section headings corresponded to occupations; and a comparison was made between the work descriptions in four sections of the standard method and the work experience reported by operatives in different occupations encountered during the operative skills enquiry. The result is presented in Fig. 1 of this appendix; a shaded square represents a response to a given type of work by more than 30% of an occupation and numerals indicate percentages below 30%. Plant operators, who can be associated with any of the operations listed, have been omitted from the figure. Neither the main sections nor the individual work description items were found to provide an accurate guide to trade identification. Only in isolated instances does one occupation span all the work of a section and even then each piece of work may also be undertaken by several other trades. No item of work is tackled exclusively by one trade and most pieces of work divide in practice into tasks each undertaken by a different operative or labour group.

E-3 The BRS study of operatives skills[18] showed that occupations could be classified into the following broad groups.

Main trades (carpenter, bricklayer, plasterer, plumber, painter) each undertaking a wide range of work which in some instances overlapped and which was not completely indicated by current trade titles. Certain sections of a main trade's work was also done by specialists, some of whom in turn spanned several trades.

Minority trades (slater and tiler, glazier, etc.) undertaking a narrower range of work—work which often is also within a main trade's experience.

A growing group of specialists in, for example, concreting, roofing, and internal finishes, frequently associated with particular operational methods.

Service to other trades (scaffolders, plant operators) who may be associated with any of the trades in the other groups.

E-4 It can be seen that even between these broad groups overlap is considerable. Which trade will, in practice, undertake a particular operation depends on a number of factors. The availability of men of a given occupation is one, which in turn is linked to length of run of work; a specialist will be employed only when the amount of work justifies it. Frequently operations divide naturally into tasks, each involving a different trade or labour group. Operational method also has an influence when paint or plaster, for example, are to be applied by spray rather than brush or float. The overlap or interchange of work between trades, and the influence which method and local circumstance have on who will undertake what, all make for difficulties in identifying labour resources.

E-5 When building used only a limited range of materials—stone, brick, timber, lead—and the constructional methods appropriate to each were standard, the material provided an acceptable basis for occupational classification. With the introduction of new and non-traditional materials, hand tools and mechanical plant, and with the

adoption of new methods and techniques which have extended the work of the ma trades and have led to the appearance of specialisations, material alone has ceas to be an adequate indicator of occupation.

E-6 The studies of building operatives' work made by BRS indicate that at least fo factors may determine the range of work adopted by a building occupation.

Materials: in addition to the traditional effect of generic type of material, differe occupations arise out of differences in form, size or shape of materials.

The function of the work-piece: in some circumstances the provision of work-piece which fulfils a major design function may be sufficient to defi an occupation which cuts across all material, tool or method boundaries, as the case for example with the roofer. At another level minor differences work-piece function produce alternative occupations, as, for example, betwe the painter who applies decorative coatings and the painter who specialises protective coatings to steelwork.

Operational method: in some instances the actions performed (as indicated b the verb in the operation description, cut, place, joint, fix, etc.) is sufficient distinguish occupations—the drainlayer from the pipe jointer, the bar bend from the reinforcement fixer.

Tools/Plant: varying tool skills can distinguish one occupation from anoth and common tool skills can lead to overlap or the blending of two occupatio into one. In some circumstances tool skill differences are synonymous wi operational method differences. Examples are mobile crane operator, tow crane operator, woodcutting and sanding machinists, and such occupatio as spray painter, chase cutter.

E-7 The varying influence of these factors could be taken into account if the Guide Occupational Classification in the Construction Industry prepared by the Departme of Employment and Productivity is compounded with the occupations recorded b BRS observers during the Operative Skills Enquiry. For example:

Reinforcement bender and fixer
steel bender, assembler and fixer
fabricator
bar bender
reinforcement fixer

Painter and glazier
Red lead (protective coatings) painter
Spray painter
Industrial painter
Painter and paperhanger
House painter and decorator Artex finisher grainer
Signwriter, writer glass painter letterer advertisement painter gilder
Polisher, french polisher
Glazier patent roofing glazier plate glass fitter
Lead light glazier leader lead light fixer stained glass glazier

E-8 The factors also suggest a format for a set of Occupation Data Sheets, to indicate th range of work appropriate to a named occupation.

Example 1

Reinforcement fixer and bender

Function of work-piece	reinforcement to cast concrete members
Materials	mild and high tensile steel in individual lengths fabrications
Operational method	cut to length, bend to shape, place in position, fix

Tools	jig, vice, bending block, bending machine pincers, bolt croppers, welding plant, stressing plant, guillotine
Special techniques	welding, pre-stressing, post-tensioning
Additional capabilities	read bending schedules, read work-piece drawings, set out, work at heights and in confined spaces.

Example 2

Painter and decorator

Function of work-piece	decorative, masking and protective coatings and coverings
Materials	paints, varnishes, stains, adhesives; flexible sheets and trim (lengths) of paper, plastics, etc; masking, filling and softening agents
Operational method	prepare surfaces, remove old surfaces, make good surface defects by filling, moulding, etc, spread liquid coatings by brush, roller or spray, place flexible sheets and lengths
Tools	brushes and rollers for applying liquids; cutting tools, spatulae, solid and liquid abrasives, burning-off tools; brushes, rollers, etc, for plane surfacing; mixing, blending, straining equipment; plumb rules, straight edges, stencils, etc, patterning and texturing tools, Mechanical plant—spray guns, compressor air brush, sand blaster
Special techniques	Graining, marbling, signwriting, gilding, glazing, french polishing, wall tiling
Additional capabilities	Working at height, working off cradles, artistic design, supervision.

The work undertaken by operatives in a range of occupations compared with the sectionalised work descriptions of the standard method of measurement for building work

	Brief description of the type of work/operation	S.M.M. Reference	General Labourer	Pavior/Grnd Surface Worker	Pipe Layer/Drain Layer	Concretor	Concrete Finisher	Reinforcement Fixer	Specialist Shutterer	Concrete Erector	Cladding Erector	Bricklayer	Mason	Carpenter/Joiner	Ceiling Fixer	Slater/Tiler	Roofer	Felt Roofer	Asphalter	Plasterer	Wet Floor Layer	Terrazzo Fixer	Wall Tiler	Floor Tiler	Dry Liner	Plasterboard Fixer	Partition Fixer	Painter/Decorator	Plumber	Bricklayer's Labourer	Plasterer's Labourer	Plumber's Mate	Timberman
Earthwork	Site clearance, site preparation	D										25																					
	Excavation, earth moving																																
	Ground surface treatments		10																														
	Planking and strutting		10										20																				
Concrete work	Handle and place concrete	F						5				20																					
	Concrete finishing		15			20																								20			
	Reinforcement		20							25																							
	Shuttering/formwork		5		10	25	15						20																				
	Place precast structural units		20		10		15		10			10																		10			
	Place precast pavings and kerbs					25						15	5				10													20			
	Place precast lintols, copings etc.		25		10		10		5			25																		20			
Roofing	Slating and tiling	M								5						15															5		
	Rigid sheet roofing										10																		10		10		
	Bitumen felt roofing										5				20	15																	
	Sheet metal roofing															15	25																
	Sheet metal flashings etc.														10	15	10	20															
Plasterwork etc.	Rendering	U										15			25																25		
	Plastering											5																			15		
	Thrown finishes												10		25																15		
	Screeding												20		20																25		
	Quarry/terrazzo tiling												20		5				15	20				20									
	Mosaic fixing																		5														
	Wall tiling												15	15						20				25					10	10			
	Floor tiling													10					5	25													
	Ceiling tiling													20					5														
	Fix plasterboard																														20		

Appendix F

Classification facets

F-1 The suggestions contained in this appendix are put forward as the opinion of the team after their involvement with the study. It is not intended to pre-empt the prerogative of existing organisations in the industry. Examples for unusual facets are given so as to indicate a possible content.

Building type

F-2 This category provides a general descriptor for data of interest to clients and to architects (e.g. price data), to the design team (e.g. is the performance of a system or a commodity suitable for use in schools, dwellings, etc., or to state the performance of a system (cooking spaces) when associated with a building type (primary schools)). Elsewhere in this report it has been argued that fine distinctions between building types are not required because, in practice, each project is made up of a different assembly of functional spaces and systems, and performance should be related to these. Despite this there should be sufficient hospitality in facets to indicate design solutions related to particular building types, e.g. detached, semi-detached or terraced housing. Further discrimination could be obtained by compounding this category with conventions for layout and arrangement.

F-3 No examples are given: this facet is in common usage.

Functional spaces and systems

F-4 It is possible that this facet should be divided into two sub-facets, the first dealing with the activities that are to be housed (including external works) and the second with spaces and systems that serve these activities, an approach suggested by Mr. G. A. Atkinson in his capacity as Chairman of CIB Working Commission 45, Human Requirements and Building Design. Some activities will occur in every building type although their nature and the space and equipment will vary. Others, child care for example, only take place in a few building types.

F-5 The examples of the two sub-facets are:

functions communications relaxation personal toilet the provision and consumption of meals building care fitting and fixtures care personal possessions care child care etc.

system habitable, storage internal circulation: total, horizontal, vertical etc., food preparation, cooking and distribution sanitary (excluding disposal) disposal: total, solid, water-borne etc.

Building element

F-6 This category, intended to divide projects into parts about which designers can make meaningful choices, is too well known to require further description, except to comment that element lists should provide for three distinctions; elements that are not complete, elements that are complete, and elements that are necessarily associated with other elements. These distinctions will be particularly useful in price analysis, in that alternative analyses can be given for e.g. the external wall element with and without its associated finishings. The present *building element* facet does not, however, necessarily indicate form or technical solutions. It is recommended that elemental lists should be sufficiently hospitable to include 'form' when this is

important, is particular to and characterises an element e.g. stairs: straight, d legged, helical; roofs: flat, pitched mono, pitched double, monitor etc.

F-7 No examples are given because this element is in common usage.

Technical solution

F-8 This category is provided in order to indicate the essential characteristics of the desi solution without recourse to drawings, a facility not afforded by the previc categories. Technical solutions are seen as a convenient peg for the feedback cost and price information and as a proxy for a category describing constructi methods, in general rather than in specific terms, and it is expected that *techni solutions* will be used in conjunction with *building elements*. They would enal possible solutions to be identified given a building element, its form, and performan (structural, exposure, fire rating, durability, cost), in addition to acting as a use category for data retrieval.

F-9 The problem of distinguishing one form of construction from another is difficu because a balance has to be struck between description of work-pieces (too diffe entiated to classify data) and very general descriptions (too coarse to usefu identify solutions). One approach, indicated in Building Regulations 1965, is form broad categories (A), with further sub-categories (B, C, D etc.) to distingui between broad choices designers can make. The final categorisation is formed several sub-facets, the number depending upon the interests of the user.

F-10 An example of such a system would be:

A *framed structures*

B *frames with pinned joints* with straight members with curved members
frames with rigid joints with straight members with curved members
space frames prismoidal other etc.

C *in situ concrete* reinforced post-stressed
precast concrete reinforced reinforced, post stressed pretensioned pretensioned, post-stressed
steel and steel alloy etc.

D *not encased* *encased* with brick with concrete
hollow protection asbestos-cement plaster etc.

F-11 At one level of detail the broad classification, framed structure, may suffice to speci the technical solution, at another—perhaps concerned with fire-resistance—th technical solution would not be sufficiently defined unless all three categories we used, e.g. frames with rigid joints, in-situ concrete reinforced, encased with concret

Commodity classification

F-12 For the purposes of the construction industry it is suggested that commodities shoul be classified to take account both of the arrangements of merchants and manufac turers, and of the functions served by commodities. In this way merchants an manufacturers would be able to prepare a set or sets of catalogues forming a series and users obtain related catalogues whether or not these are produced by the sam merchants. A possible solution to this problem is indicated in Table 3. The arrange ment proposed is catalogue orientated in that the supply organisation and the broa function of the product identifies a catalogue and further sub-categorisation section of that catalogue.

F-13 General properties, performance and commercial information that will be part o the records held in the central commodity file are suggested by Table 1.

Construction method

F-14 So far contractors have not demanded a category for construction methods, probably because these are adequately indicated by the form of the building, the building elements, the technical solutions, and by the plant selected. Despite this it is suggested that any comprehensive system of data co-ordination should reserve a category for *construction methods* which contractors could use on an ad hoc basis in order to provide information about preferred methods of working. As long as there are no agreed methods for recording productivity, it is probably wise to leave this facet unspecified.

Work section

F-15 The purpose of this facet is to provide a convenient key to organisations undertaking building construction, rather than to occupations. On the grounds of common usage, the work sections listed in the Standard Method of Measurement (probably grouped in Trades) provide a convenient starting point.

Work element

F-16 The case for this facet has been argued from the need to encourage the collection of data about productivity on sites. Experience of the Building Research Station indicates that this is most cheaply achieved by activity sampling. If activities can be sampled only infrequently, the activities recorded will have to be coarse; if frequent sampling is possible, information can be collected in a finer degree of detail. In either case, the information collected will be of two kinds, the first dealing with *general activities* such as unloading, handling, preparatory work, the second with *construction activities,* i.e. activities that directly contribute to the growth of the building. In practice these latter activities are described by the work-piece that is being created, rather than by the movements the men are actually carrying out, which can be observed only through intensive work-study (Tables F1 and F2).

Table F.1

ieneral activities (employed for studies by Mr. W. S. Forbes of BRS)

lote Locations are parts of projects, including site areas, as defined on drawings or location schedules.

ctivities	Detail of Activity
NLOADING	Includes: Unloading materials into compounds or stores, to be subsequently handled for 'building in' or using in the 'Location Areas'. Unloading materials direct into the 'Location Areas'
ANDLING	Handling materials from the compound or stores to the 'Location Areas'. Handling materials during the operation for immediate use. ('Immediate' includes pre-loading of bricks on to scaffolding etc., prior to use and similar pre-loading) Handling materials from one 'Location Area' to other locations, or within the same location area, i.e., double handling or R (repeat work).
ETTING-OUT	Setting out, erecting profiles, and sight rails etc.
LUMBING, LEVELLING AND LIGNING	Obtaining accuracy during construction and checking
REPARATORY WORK	Preparation of material for subsequent fixing or application, e.g., fabrication of bulk materials into pre-fabricated building components; in-situ preparation of materials, components etc., prior to or during the operation

CONSTRUCTION ACTIVITIES*	An operation *directly* contributing to the growth of the project and normally described by the work-piece that is being created
CONNECTING TO EXISTING SERVICES	Breaking into service cables and pipework for jointing branch and/or other connections, including fixing the junction box, troughs, saddles, sleeves, turn-cocks and/or similar jointing fittings
TESTING SERVICE INSTALLATION AND APPLIANCES	Testing out completed and semi-completed service cables and pipework, including the appliances, during and after installation of the services and fittings etc
CLEAN-UP	Cleaning and clearing up after or during an operation
SUPERVISION	'Non-working' supervisory staff, e.g. visiting, general and trade foremen and charge hands not engaged on actual building operations
NOT WORKING	Operatives not working while at the work place
WALKING	Operatives not working and not at the work place
RAINED OFF	Operatives not working because of inclement weather
STANDING	Operatives not working because of early or extended work breaks
ABSENT	Operatives not observed during the recording period
REPEAT WORK	The extra work undertaken to completed operations, prefabricated and fully finished components in correcting making good arising from defective workmanship, materials and/or design and organisation
	NOTE Repeat work must be described in the site diary, also an activity must be given.

*The incidence of construction activities varies with the type and complexity of project, and typically ranges between 50 and 80% of the total time.

Table F.2

Examples of construction activities are:

Activity	Sub-activities	Includes
Concrete Ground Floor Slabs (Houses)	Lay polythene damp-proof membrane	Dressing membrane up to horizontal dpc and for warm air ducting
	Place concrete in ground floor slab	Thickening slab under load bearing partitions
	Place reinforcement in ground floor slab etc.	Placing mesh reinforcement
Brickwork and blockwork walling—DPC to First Floor Level (2 storey houses)—DPC to roof plate level (single houses)	1 brick thick com. br. wk. party walls	Horizontal and vertical dpc and cavity gutters, closing cavity, and building in grounds for fixing frames etc.
	$10\frac{1}{2}$'' thick cavity brick and block external walls	
	$10\frac{1}{2}$'' thick cavity brick and block flank walls	
	Build in external door and window units	External door and frame units, metal windows and cills and fixing cramps
	Build in pre-cast concrete units	'Spanlite' pre-stressed lintols and painting with bitumen.

Operative occupations

F-17 As has been pointed out there is no necessary match between the trades of the Standard Method of Measurement and the operatives engaged to complete work-pieces (Appendix E), and it is suggested that pending the results of the review of the occupational structure of the industry, a classification could be derived from the 'Guide to occupational classification' issued for the guidance of the staff of the Department of Employment and Productivity, filled out by detail provided by the Report on Building Operatives' Work

F-18 At a subsequent date occupational classification might be extended with advantage to other occupations including management, supervision, design, estimating, planning etc., so that the resources available can be better matched to vacancies and so that future resource needs can be more readily predicted.

Plant and equipment

F-19 Although no categorisation commanding national acceptance exists and there is no clamorous demand for one, it would seem that advantage would be obtained from an agreed method of categorising plant by its performance, rather than by referring to a particular type of plant manufactured by a maker. The type of classification envisaged is to distinguish between powered and other equipment and to classify by both their function and their performance. One such system has been devised for a firm of contractors and it is possible that arrangements could be made for this to be more generally available.

Appendix G

Implementation: priorities and costs

G-1 The Station was not asked to study the practical consequences of implementing the recommendations made in the Report, other than to ensure that they were feasible. Nevertheless many readers will wish to have some idea of the priorities as we see them, and of the probable cost of implementation. Therefore, in this Appendix, priorities are established and each feature of the framework is reviewed in order to estimate the number of staff required and the probable cost of consultancies and the like. Naturally these estimates are mere cock-shies and no account has been taken of what income might accrue from some items. It should be noted that implementation could be achieved in several ways and at differing tempos, so that a single estimate of work is perhaps misleading: nevertheless, it is believed that the order of cost is not too far out.

Priorities

G-2 Because the greatest savings would appear to accrue to manufacturers and suppliers through the streamlining of their procedures, the highest priority should be given to establishing a system for identifying commodities. As has been explained, this would pave the way to the development of a central commodity file, which is also regarded as having widespread value. Concurrently, a start should be made to improve production information by producing a standard building specification, by improving the format and grouping of items within Bills of Quantities, to relate them to the management of contracts, and by relating methods of measurement to the feedback of productivity data. Subsequently conventions should be developed for the content and presentation of production information as a whole. The initial group of priorities would be completed by extending the present classification categories to include functional spaces and systems, together with the necessary and related conventions for performance and feedback data.

G-3 Other aspects of the framework would take longer to develop, but could be started immediately. A start could be made on the development of related suites of computer programs, especially for structural engineering and the management of construction; whatever the demand, the tempo achieved is likely to be dictated by the number of programmers available. The catalogue of commodities 'identified' by manufacturers would indicate the extent of a central commodity file and the sections that merit early action, e.g. those with a high technical content. Compilation of the initial file may take five years, but can commence immediately priorities have been agreed and also the form and content of manufacturers' information.

G-4 In order to be able to draw on expert knowledge and to inject new ideas and thinking, it is suggested that the central organisation should make considerable use of consultants and other organisations. This will keep the full-time staff to a manageable number and meet the demands produced by the nature of the work. Some of the tasks are continuing (including advisory service, the servicing of consultants and advisory committees, the management of the commodity file etc.); some will entail a considerable initial effort that will diminish with time (the development of suites of procedures and the central commodity file); some are cyclic because of the need to review and extend work already completed.

The effort entailed

G-5 *The preferred vocabulary* Setting aside the cost of the contract already placed by CIRIA the task of maintaining the vocabulary should not exceed one man year per year.

G-6 *Classification facets and conventions* Since the classification facets and conventions must serve the needs of practitioners in design and construction, it is probable that they are best prepared by full-time specialists responsible to industry-based working parties. It is envisaged that consultants will be appointed, and the task of servicing them and the working parties will be carried out by the central organisation. The conventions must, of course, be related to the preparation of suites of related procedures.

G-7 The demands placed on the central organisation will depend upon the tempo of work; if the tasks outlined in the report are tackled in a period of 5 years it is possible that the consultants and the working parties developing the classification categories and the conventions could be serviced by a secretariat of 7, who should be able to tackle some work on their own account. Fees for consultants to develop conventions for feedback and performance (£20 000 for computer graphics (£20 000), for measurement (£20 000) can be foreseen and provision should be made for £15 000 p.a. for the first three years and £10 000 subsequently. If the central organisation is also responsible for preparing the national building specification, provision should be made for a staff of 6 and a further 4 if a specification for civil engineering work is prepared.

G-8 *A central commodity file* It is assumed that the central organisation would allocate the identifiers for commodities, at least in the first instance. In the long run it will be necessary to co-ordinate manufacturers' information, (a pre-requisite to establishing a central commodity file). It is probable that the management of this part of the system could be accomplished by a staff of 2 with a further staff of 4 (supplemented by consultants) to determine the information to be presented.

G-9 The central organisation should initially concentrate on determining the context and presentation of information, an essential preliminary to preparing the file. Two major suppliers currently stock between 50 000 and 70 000 distinguishable items having main entries in a catalogue and excluding variants in size or other single characteristics. Hence it is expected that a central commodity file for building materials would contain about a 100 000 entries initially, and that additions and amendments to this file might be at the rate of 10 000 entries per year, in order to enter new items and to expand the scope of the file. It is assumed that the manufacturers together with the merchants would supply the information in a prescribed and agreed form, and that the staff mentioned above would be able to co-ordinate this activity.

G-10 *Procedures* In the report it has been argued that the number of programmers likely to be available to the construction industry will act as the main constraint on the development of suites of related computer programs. It is not expected that procedures will be developed centrally but that this work will be undertaken by systems analysts and programmers attached to other organisations, including universities, consultants and commercial firms and supported and co-ordinated by the central organisation with a staff of 4. Until the demands the construction industry could reasonably make have been discussed with the Ministry of Technology, and with the National Computing Centre, it would not be possible to estimate the demands that could be made for programming work. However, an estimate has already been made that the construction industry spends at least £1 000 000 per annum on programing, and it is reasonable to assume that 20 per cent or £200 000 could be diverted to prepare programs for common use.

G-11 *Assigned codes* Since the majority of the codes will be related to procedures, codification and development of procedures will go hand-in-hand. The central organisation will probably use one person to deal with the application of coding.

G-12 In addition, the central organisation will have to fulfil advisory and promotion rôles and to survey research and development in the field of coding and data co-ordination. Advisory work should be handled by the staff already suggested, with the support of an additional 2 staff to collect and disseminate information, assuming information about computer systems will be obtainable from manufacturers or from the National Computing Centre. Promotion will include education, the support of lectures and

G-13 making available advisory leaflets. The central organisation is likely to be directly involved, including providing material (texts, slides, films) to be integrated into the education framework, hence provision should be made for a staff of up to 5. Although the survey of research and development is a proper rôle for a central organisation it is expected that the funds for research work will be drawn from elsewhere. Nevertheless, it would be prudent to allocate a sum to sponsor urgent essential work. The survey work would be spread between the staff so far mentioned.

Staff

Vocabulary	1
Classification facets and conventions	7
Central commodity file	6
Procedures	4
Coding	1
Advisory	4
Promotion	5
	28

Costs

G-14 The initial costs of establishing the organisation should of course not be overlooked, but if £5000 a year is taken to cover overheads, office charges outside London, and administration, the annual cost would be around £140 000. Adding the responsibility for the national building and civil engineering specifications would add £50 000 a year. The consultancies mentioned in this appendix might well run at £250 000 a year initially, two thirds of which would be devoted to procedures, and it is from the use of these that the biggest income could be envisaged.

G-15 The cost of establishing the central commodity file will be heavy. If one takes £50 per item as on average cost for preparing the record, then the initial cost might be £5M spread over 5 years, and the annual continuing cost might be £500 000. Against this must be set the savings given in para 9-2 conservatively estimated at £30M a year.

Appendix H

An illustration of a code for the construction industry

Prepared by D. Whiteside BSc

Introduction

H-1 The coded information structure sketched in this appendix has been developed directly out of the requirements thrown up by the study and described in Chapters 4 and 8 of the Report. It is presented purely to provide an illustration of what a code structure might look like and has certainly not been developed very far or in great detail; further development would, of course, involve reaching detailed agreement with users (the various sectors of the industry) on the various headings etc. that need coding. The code structure described here can be used as a framework to accommodate a number of sectional codes and can thus be 'bent' to accommodate a wide range of uses. It is not the most efficient for every specific use; on the contrary a code designed for a specific purpose will be more efficient for that purpose. Nevertheless, the effort expended in developing this general type of system is likely to be considerably less than the total effort expended on a proliferation of independent special codes and on the consequent need to translate from one to another.

H-2 It is important to distinguish between the code structure and the information it carries. In some cases the actual information to be carried will be decided by the individual user (a contractor's site experience on jobs; a designer's own know-how in particular areas of design); in others, wide agreement will be needed (the content, for example, of a central commodity file): but in all cases the code framework into which this information fits will obviously be best if it is agreed throughout the industry. The code structure can best be regarded as the means of gaining ready access to information, whether stored in documents or in computer files, and of allowing it to be manipulated in desirable ways.

H-3 Four code fields are suggested, as follows. (In formats 'a' denotes any upper case letter and 'N' denotes any numeric digit).

1 **Primary classifier with format NaaaN** This has three distinct fields within it and is crucial to the code framework. In many files, it would be the main identifying label to the areas of information to which the code would give access. For instance 3 DOR 1 and 2 BSE 1 would be used with coded information about *doors* and *building structure,* where the first characters (3 for doors and 2 for building structure) indicate that they are being treated as a *resource* and as a *building element* respectively. Other primary groups cover the other categories mentioned in the report.

2 **Subclassification NNNNNN** This field will contain a sub-faceted classification of the most important aspects of the subject matter covered by the primary classifier that are amenable to classification. For example, for doors (3 DOR 1), these aspects might be *dimension, action, construction* and *fire-rating,* and using the example of para H-21, a subclassification 073130 would indicate dimension $1\frac{1}{2}$ in. x 2 ft 6 in. x 6 ft 6 in. (07); top sliding action (3); flush solid construction (1); fire rating of 1 hour (3).

3 **Location NNNNNN** This field would be for locational information associated with the primary classifier, and it would be broken down into facets. Thus in a project file, a particular door might have for this field 09 63 02 indicating that it would occupy door opening number 2 (02) in room number 63 on the ninth floor of the project.

4 **Specification** The definition taken here for specification is very broad and covers all information that it is useful to associate with the primary classifier

including statistics (e.g. cost) and links (e.g. commodity identification numbe etc.) to almost any part of any data system established. This section might be o free format though for practical reasons it is hoped that fixed format fields will be appropriate for at least parts of the specification in on-file documents. Four types of field are suggested in para H-17, and these together with the examples illustrate the diversity that is envisaged.

H-4 No one user would ever need to use—still less to know—the complete code. Most users would find that they frequently need certain parts, and they would rapidly become familiar with them. The extent to which users needed detailed information would determine the level of the code to which they would have to go. Thus access to past jobs would need only the primary classifier with the sub-classifier or the location code. Reference to paragraph 3 above shows that this means using 11 symbols. For many purposes, the first five symbols will be the same and are to some extent redundant; they merely lead to 'building type' or to some other main classification.

H-5 Essentially what the code does is to provide access to whatever records an organisation uses, and the possibility of manipulating and linking the data the records contain. Thus the extent of the code used by any one organisation will be determined by the detailed way in which it wishes to structure its records and by the manipulations and links it wishes to effect.

Features of the code

General

H-6 The information structure and the codes have the following general properties:

Current practice has been embodied in the basic structure only in a very general way.

The information structure is capable of extension and the suggested codes should cope with foreseeable extensions.

Development of the structure in parts should be possible.

Alpha characters in the codes are only used where short mnemonics are useful and may easily be derived, or where the larger character set of the alphabet is advantageous, e.g. 3 DOR 1, 2 BSE 1, the primary classifiers for doors, building structure.

The codes are basiçally of fixed length field. The choice of the field requires and its positioning will depend on the use required and the type of document to be handled. (See later for the development of a commodity file and a possible method of use). Indeed, whether the codes will be used other than as a guide to the software producer will largely be a matter of time, cost and training of the user in the building industry.

The code structure goes some way to enabling the pieces of information most frequently used to be accessed most readily and expressed by the shortest codes, e.g. the subclassification facets (see paragraph 11) and property indicators (para H-17-3). In the case of building structure, sub-classification facets with only three significant numerical facets might for many purposes give a sufficiently fine classification. Thus (using the code key of para H-26) the code 2 BSE 1 712 . . . would inform us that we have a *building structural element* described as a *framed, pin-jointed structure with straight steel members suitable for low rise low weight carrying buildings*. The addition of property indicators, *f,g* (see para H-29) would add that it is *designed to withstand special subsidence and fire risks.*

It is capable of accommodating classifications and codifications of interest only to particular sectors of the industry or developed outside the main framework of the system, e.g. identification numbering by manufacturers, commodity codes controlled external to construction industry such as NATO codification, ad hoc coding within project, etc.

Primary classifier (P) = NaaaN

H-7 This section of code is intended to be an identifying label to areas of information of a classified, locational and specificational nature carried by the rest of the code. What these areas of information actually are will depend on this classification. Thus, for example a bath, a wall and a door will all have different information associated with them. (These areas of information should also be capable of independent development by the collaboration of persons engaged in a particular field with reference to a central authority which would define the area covered by the primary identifier, establish a unified vocabulary and provide rules for ensuring compatibility with other areas of the code). Since interpretation of the code relies heavily on this primary classifier it is considered advisable for it to be easily memorised.

It is suggested that the classifier be divided into 3 sub-fields N, a a a, and N, which are now discussed in turn.

Classifier group N

H-8 This is a single numeric character. The groups to which it would refer reflect current practice to the extent that they assume that information about building is in the form of drawings and other documents having various degrees of coarseness which are worth recognising at a high level in the code. They also assume that management and design aspects of construction can be differentiated.

The groups of classifier suggested are: building and site aggregations resources work-pieces with some possible other groups.

Building and Site (P) = 1aaaN

In the light of the study, this might have only a few classifiers say *building type,* functional space and construction site which may have associated with them information of a nature general to large parts of projects such as planning solutions, user types and building performance. Coded information in this group will be useful as document headings for project information and technical information and will be used in the specifications associated with primary classifiers of all groups. The areas of information covered by this group will be mostly required early in the project during feasibility studies.

Since it may be desirable to have whole documents retrieved in response to searches then in this classifier group it might be worthwhile replacing the subclassifier and location by sets of keywords.

Aggregations (P)=2aaaN

These are classifiers based on definitions which serve specific tasks mainly during the early stages of design realisation. For instance, a breakdown of a building into *functional system, building element* and *work section* might be appropriate. The areas of information associated with the classifiers may be used for drawings and summary statements and might facilitate answering the question 'What components are required?' The links provided in the 'specification' part should be such as to enable the definition of an element to be flexible with possibilities of variations in different projects.

Resources (P)=3aaaN

Primary classifiers in this group could provide the chief points of co-ordination for an information system. They will include objects recognisable on drawings (similar to CLASP features) and formless materials which may be considered as commodities in some parts of the construction industry. The groups of objects covered by any primary classifier would probably be determined by the function they perform.

Uses for the codes of this group will include *central commodity catalogues* to enable selection of components by performance and cost; coded building project information for feedback and for generation of schedules; and resource estimates and for programme planning. Links may be provided in the specification to facilitate the retrieval of drawings and to enable unique identifications

to be made for ordering and accounting. Information about *plant and equipment* would fit into this category.

It is anticipated that product information both in computer storage and in normal hard document form, e.g. drawings and printed catalogues, could be ordered according to the primary identifier—the primary key—though there are many other parts of the code which might be used as sort keys for this purpose.

Work-pieces; (P)=4 aaa N

These items are complementary to the commodities, components and sub-components of the previous group since the definition of work-piece ensures that the classifiers will serve construction and therefore have associated with them information not discernible from the design of the building or the incorporated components when completed. Often the names of classifiers for work-pieces will be the same as some of those in the commodities and component group and it is desirable that the classifier names generally should be developed within the framework of that group. However, the associated information will be of a different nature, for instance it will show the times and sequencing of the work-piece relative to others, *operative occupations* required by the contractor, tools and plant required by the operatives and the *work elements* required for the completion of the work-piece.

Other groups

There are other areas of information which, though not central to the whole construction process, might nevertheless be rationalised by developing classifications with their associated codes compatible with the rest of the system. One such group of information could be termed management, with classifiers (code format (P)=5 aaa N) being broad classes of *operative occupations* with a finer classification in the sub-classifiers. Specification would allow for wage rates, efficiency rating, types of work-piece within an operative's experience, etc. Another group might be a set of classifiers associated with *work elements* (code format (P)=6 aaa N). In this case specification may include phraseologies required by operatives in carrying out the various work elements. Both these groups of classifiers could be used in the detailed planning of projects and the contractor's personnel file could be based on the operative occupations codes. In addition the short codes would be used elsewhere in the data structure particularly with work-pieces.

A further group might be some classifiers associated with *design* (code format, say, (P)=7 aaa N). For instance, classifiers might be allotted to particular areas of *technical design data*, or for facilitating the acceptance of standard software for standard procedures, or for aiding the adoption of standard file structures.

Classification and coding of regulations and standards might provide classifiers for another group but it is hoped that there will be classifiers elsewhere in the system, for instance in 'functional systems' which will serve for these purposes. Two other possible categories mentioned in the main report but not fully developed here are *technical solutions,* and *construction methods*. Technical solutions might in fact best come within the sub-classification fields of the primary classifications 'functional systems' and 'elements'.

Classifier name aaa

H-9 This is a three-letter mnemonic based on a name which will serve to identify the classifier—a thesaurus of terms would be helpful for establishing suitable names. The mnemonic could be constructed according to the following rules:

If a single-word name, take the first letter and following consonant (or the second letter if no consonant) and last letter.

If a two-word name, take the first letter of the first word and the first and last letter of the second word.

If three words or more, take the first letters of the first three significant words.

Classifier uniqueness N

H-10 This is a single numeric digit allowing unique identification of classifiers even with simple rules for forming the mnemonic. This could also be used for creating more than one classification system for a given area of information, or for splitting an extended system of classification into two or more parts.

Sub-classification (C) = NNNNNN

H-11 This field of code is envisaged as being similar to both the 4th facet of BDC and the attribute classification of West Sussex CC and it should be used to classify the most important, easily classifiable information associated with each primary classifier. In general, therefore, it will be the part of the code used most frequently to answer the question 'What type?' once the primary class has been established. It might therefore be used for the secondary ordering of documents in filing systems. If the classifiers have important technical solution classes, performance classes or established classifiable standards then these may be in the sub-classifier.
It is suggested that any arrangements of facets within the field be permitted e.g. 2 facets of 2 digits and 2 facets of 1 digit. (BDC has 6 facets each of 1 digit).

Location (L) = NNNNNN

H-12 This section of code is also intended to be dependent on the primary identifier, but possibly to a lesser extent than either the classifiers or specifiers. It might also be useful to make it dependent on the type of document. In most meaningful pieces of information there is locational information which is usually of interest for complete identification. This type of information need not be given positional precision in the form of co-ordinates or distances but can usually be of a coarser nature which can be quantified. It is this type that the locational identifier is intended to contain.

H-13 It is proposed that this part is 6 numeric characters which might be used in a variety of groupings. For instance, in project information the locational part might consist of the 3 most appropriate code fields taken from a hierarchical set of codes defining location in a project, ranging in increasing coarseness from room surface and room number through storey number up to project number. In commodity catalogues the source of information such as identification code number or location code for the manufacturer might be suitable contents. In the report the GIRO number of the firm is suggested for the manufacturer's identification and this would entail 7 or 9 digits, instead of 6. If this were in the location field then the identification contained in the 'specification' would not need to repeat it.

Specification

H-14 The definition of specification is assumed to cover any information which may be usefully associated with the primary classifier.

H-15 The types of information expected to be included are:

Statistics e.g. costs, dimensions, weights, times, etc.

Classifications and identifications used universally within the industry, peculiar to particular firms or developed outside the industry. Repetitions of the sub-classes, perhaps in a different form, could be expected.

Definition of relationships between the classifier and information associated with other classifiers of any type or documents not fully incorporated into the system. For instance in the specification of *door* there might be included data such as the identification number of the adjoining *door frame* or the type of hinge that may be fitted.

Properties which can be broken down into yes/no type categories.

Verbal or other information which cannot be coded, or is a repeat of important information for reinforcement purposes, or a block of information which may be retrieved with little discrimination.

H-16 The types of information required by all the classifiers are very numerous—they include the CIB Master List of Properties with further breakdown—and yet each classifier will require only a small fraction of them. Therefore it is suggested that some of the specification codes should be dependent for their interpretation on the primary classifier while others will be reserved for general use.

H-17 Four fields are suggested.

1 General specifier: βα/(field), where β is any of XYZ, and (field) is used for a statistic or other sets of symbols whose significance is defined by the preceding βα which will be called a 'general utility tag'. This will be used for information types of general use e.g. XC/75·4 could represent a 'total cost' of £75·4.

2 Local specifier: γα/(field) where γ is any of the letters A–W. This will be similar to the general specifier except that the 'local utility tag' i.e. γα will not be interpretable without knowing the classifier e.g. DL might be 'length of pipe' when associated with *pipe* but 'height of door handle above floor' when associated with *door*.

3 Property indicator: a, where 'a' is any lower case letter a-z. This may be used to indicate whether a particular property is present or not. It is intended to be dependent on the classifier for its interpretation.

4 Text: *followed by any permissible symbols. It is envisaged that the uncoded free descriptions will be an important part of the information system and might be subdivided into various sections which would become independently retrievable. If these become extensive a separate postco-ordinate retrieval system might be developed for them, treating each description or section as a 'document'.

Examples of the key to the code

H-18 This section gives examples of what the code key (i.e. a list of the codes and their significance) might be like for codes associated with the following classifiers:

Building type	1 BTE 1
Building structure	2 BSE 1
Door	3 DOR 1
Reinforcing bar	3 RBR 1
Concrete	3 CNE 1
Brickwork	4 BRK 1
Essential graphic geometry	7 EGG 1

Notes

$N_1 \ldots N_6$ represent any digit in the 6 positions of the sub-classification field, the subscripts being added for reference purposes.

In specifications, use of (P)+(C), (L)+(C), (P)+(C), etc. indicates that these fields of codes are expected after the utility tag. Symbols of the form (αα) indicate that the contents of the (field) of some other specification may be substituted.

In the examples it is assumed that many of the properties will have standardised units of measurement (i.e. conventions) which are indicated in the code keys. However, an alternative would be for a set of distinguishable abbreviations for units to be included as part of the (field).

Restatements of sub-classifications are given references in the sub-classification headings, e.g. in the sub-classification of *Building type,* floor area (FA) indicates that the rough class of floor area may be complemented by a more accurate value in the specification (field) associated with the utility tag FA.

General utility tags may be used with any classifiers but in the examples only some of those expected to be used with a particular classifier are indicated.

H-19 **Building type**

Primary classifier (P) | 1BTE1 | **Building type**

H-20 **Sub-classification (C)**

$N_1N_2N_3$	User type (UT)	N_4	Floor area (FA)	N_5	Planning form (NB) (NS) (DH)	N_6 (Spare)
	A 'classification' similar to the 'building type' classes of Anne Plowden	0	Unspecified	0	Unspecified	
		1	$< 100\ m^2$	1	Single storey	
		2	$100–400\ m^2$ etc.	2	2 storey	
				3	3–4 storey	
				4	5–10 storey	
				5	> 10 storey	
				6	Underground	

H-21 **Location (L)**=Geographical Region/Project No./Building No.

H-22 **Specification**

Utility tags (General, local & text)	Significance of (field)
XC	Total cost (£)
XD	General building drawing numbers
XR	Components incorporated
YE	Estimated cost (£)
YC	Client
YP	Professions engaged, (P)+(C)
ZC	Contractors engaged, (P)+(C)
BT	Building types in same project, (L)+(C)
CA	Circulation area (m^2)
CE	Consumption of electricity (kWh/annum)
CF	Peak electricity rate (kW)
CG	Consumption of gas (Therms/annum)
CL	Cost limit (£)
CO	Consumption of oil (litres/annum)
CS	Consumption of solid fuel
CW	Consumption of water
DC	Date of commission
DT	Date of tender
DH	Height of building (m)
DL	Length of building (m)
DW	Width of building (m)
EL	Elements incorporated (P)+(C)
FA	Total floor area (m^2)
FD	Construction finish date
FS	Functional spaces (P)+(C)
GA	Total ground floor area (m^2)
LI	Life expected (years)
MC	Maintenance cost (£/annum)

NB	Number of storeys below ground
NS	Number of storeys (total)
ON	Number of occupants
OT	Occupancy (hours/week)
SD	Construction start date
TS	Technical solution
UT	User type
UW	Underground work (m^3)
*	Description (in any format)

H-23

Property indicator	Property specified
a	air-conditioned
e	extension planned
t	temporary construction
w	windowless

H-24 **Building Structure**
This is treated here as a typical building element.

H-25 **Primary classifier (P)** 2BSE1 **Building Structure**

H-26 **Sub-classification (C)**

N^1	General type	N^2	Weight bearing class (FL) (NS)	N^3	Nature of loadbearing members (XR)	$N_4 N_5 N_6$
0	Unspecified	0	Unspecified	0	Unspecified	(Spare)
1	Articulated	1	Low rise, lightweight	1	Masonry	
2	Loadbearing cross wall	2	Medium rise, lightweight	2	Steel	
3	Loadbearing external wall	3	High rise, lightweight	3	Timber	
4	Frame, rigid joints, curved	4	Low rise, medium weight	4	In situ concrete, reinforced	
5	Frame, rigid joints, straight	5	Medium rise, medium weight	5	In situ concrete, stressed	
6	Frame, pin joint, curved	6	High rise, medium weight	6	Precast concrete, reinforced	
7	Frame, pin joint straight	7	Low rise, heavyweight	7	Precast concrete, stressed	
8	Space frame	8	Medium rise, heavyweight	8		
9	Others	9	High rise, heavyweight	9	Others	

H-27 **Location (L)**=Project No./Building No./Zone

H-28 **Specification**

Utility tags	Significance of (field)
XB	Building project (C)+(L)
XC	Total cost of structural element

YE	Estimated cost of structural element
XD	Drawing numbers
XR	Components incorporated (P)+(C)
ZF	Finish time
ZS	Start time
CU	Cost of structure/unit floor area (£/m²)
DC	Design climate
DF	Floor to floor distance (m)
DH	Total height of structure (m)
DL	Total length of structure (m)
DW	Total width of structure (m)
DS	Mean span (m)
EN	External envelope (C)
FL	Average floor loading (kg/m²)
FT	Foundations (C)
HS	Heating services type (C)
NS	Number of storeys
RF	Roof type (C)
SF	Predominant surface finish on structure (P)+(C)
SL	Special loads (P)+(L)
*	Description

H-29

Property indicators	Property specified
e	Designed for earthquakes
f	Designed against special fire risks
g	Designed against subsidence

H-30 **Door**

Primary classifier (P) 3 DOR 1 **Door** (not folding or revolving q.v. 3 DOR 2)

H-31 **Sub-classification** (C)

N¹N²	Dimensions (ft, in.) (DT) (DW) (DH)	N³	Action	N⁴	Construction	N⁵	Fire rating	N⁶	(Spare)
00	Unclassified	0	U	0	U	0	U	0	U
01	1¼″ 1′0″ 6′0″	1	hinge	1	flush solid	1	flush solid		
02	1¼″ 1′9″ 6′6″	2	pivot	2	flush frame	2	< ½ hour		
03	1¼″ 2′0″ 6′6″	3	sliding (top)	3	panel frame	3	1 hour		
04	1½″ 1′9″ 6′6″	4	sliding (bottom)	4	solid board	4	2 hour		
05	1½″ 2′0″ 6′6″	5	up and over	5	slatted	5	4 hour		
06	1½″ 2′3″ 6′6″		etc.		etc.				
07	1½″ 2′6″ 6′6″								
08	1½″ 2′8″ 6′8″								
09	1⅝″ 2′6″ 6′6″								
	etc.								

H-32 **Location (L)** = Floor or Zone/Room/Door Number
= (also manufacturer's code etc., for commodity file)

H-33 **Specification**

Utility tags	Significance of (field)
XA	Identification number
XB	Building project (C)+(L)
XC	Cost (£/each) normally without cost of fittings or viewing panel
XD	Drawing number
XE	Element within project (P)+(C)
XI	Invoice number
XM	Manufacturer's special type number
XN	Nato code classification
XP	Door number within project
XQ	Quantity surveying code (C)+(L)
XS	Stage of construction when fixed
YA	Component attached (e.g. Ironmongery) (P)+(C)
YN	National specification clause number
YW	Weight (kg)
ZA	Commodity class
ZN	Number ordered/economic batch
AV	Availability in days from order received
DH	Door height (mm)
DT	Door thickness (mm)
DW	Door width (mm)
FC	Colour of finish
FI	Finish (P)+(C)
IF	Identification of attached components (XA)
ME	Material of lipping (P)+(C)
MF	Material of structure (P)+(C)
MI	Material of core (P)+(C)
MP	Material of panel(s)
MQ	Identification of material of panel (XA)
MS	Material of facings (P)+(C)
PH	Panel height (mm)
PT	Panel thickness (mm)
PW	Panel width (mm)
SI	Sound insulation (dB)
SU	Special use (P)+(C)
UV	U-value (kcal/m^{2}h C)
*	Description

H-34	Property Indicator	Property specified
	a	Suitable for security
	b	Ventilation louvre may be fitted
	c	Fittings provided and attached
	d	Factory finished i.e. suitable for immediate use
	e	Suitable for external use
	f	Viewing panel (available)
	g	Two-way swing (available)
	h	Restoring action (available)
	l	Left hung
	r	Right hung

H-35 **Reinforcing Bars**

This example is intended to be useful for storage by computer of information concerning bars for the reinforcement of concrete and therefore could be used in the process of generating job bar schedules and for accounting and management as well as storage of project data in a form suitable for feedback. It illustrates how the proposed code might be developed to accommodate the standards incorporated in BS 1478:1967 'Specification for Bending Dimensions of Bars for the Reinforcement of Concrete'.

Primary classifier (P) | 3 RBR1 | **Reinforcing Bar**

H-36 **Sub-classification**

N_1	Quality of steel (ST)	N_2N_3	Size of bar (d) (ED)	N_4N_5	Shape Class	N_6	(Spare)
0	U						
1	Plain mild (M)		As in BS 1478		As in BS 1478		
2	High yield (H)						
3	High yield (S)						
4							
5							
6							
7	General (X)						

Symbols in ( ) are the notation used in BS 1478

H-37 **Location (L)**=Site No./Zone of Structure

H-38 **Specification**

Utility tags	Significance of (field)
XA	Identification number
XB	Building project (C)+(L)
XC	Cost
XD	Drawing number
XE	Element within project (P)+(C)

XM	Manufacturer's special type number	
XQ	Quantity surveying code	
YB	Batch number	
YD	Dispatch date	
YN	National specification clause number	
ZN	Number ordered/number in batch	
BM	Bar marks	
DA	(A)	Dimensions of bar as defined in BS 1478
DB	(B)	
DC	(C)	
DD	(D)	
DE	(E)	
DH	(h)	
DL	(l)	
DR	(R)	
ED	Size of bar (mm)	
JN	Job reference number	
SN	Structural design special type number	
ST	Type of steel	
TP, TN	Tolerances:– positive (mm), negative (mm)	
WT	Weight of batch (kg)	
*	Description	

H-39 Property indicator:– i=measurements made internally

H-40 **Concrete**

Primary classifier (P) | 3 CNE1 | **Concrete**

H-41 **Sub-classification (C)**

N_1	Cement type (CC)	N_2	Aggregate (CA)	N_3	Strength (TS)	$N_4N_5N_6$ (Spare)
0	Unspecified	0	Unspecified	0	Unspecified	
1	Portland	1	Gravel (Flint)	1	< 15N/mm^2	
2	Alumina	2	Granite	2	15–20 N/mm^2	
	etc.	3	Limestone	3	20–25 N/mm^2	
		4	Pyrites		etc.	
		5	Vermiculite			
		6	Pfa			
		7	Special			

H-42 **Location (L)**=Project No./Building/Building Zone.
=(also supplier of material)

H-43 **Specification**

Utility tags	Significance of (field)
XA	Identification number
XB	Building project (C)+(L)
XC	Cost (£/m^3)
XE	Element within project (P)+(C)
XM	Manufacturer's special type number
XN	Nato code classification
XO	Operative occupation
XQ	Quantity surveying code number
YN	National specification clause number
YV	Volume (m^3)
ZA	Commodity class
BN	Batch number
CA	Class of aggregate
CC	Class of cement
CS	Class of sand
DE	Density (kg/m^3)
TS	Tensile strength (N/mm^2)
WC	Water content (%)
*	Description

H-44 Property indicator	Property specified
a	Special hydraulic content
b	Acid resisting
c	Alkali resisting
d	Fire resisting
e	High density
f	Accelerator added
g	Special waterproof
h	Vibrated in situ
i	Precast
r	Reinforced
s	Steam cured
t	Ready mixed

H-45 **Brickwork**
This is treated as a work-piece.

Primary classifier (P) 4BRK1 **Brickwork**

H-46 **Sub-classification (C)**

N_1	General type (BK)	N_2N_3	Bond type	N_4	Type of finish	N_5N_6	Spare
0	Unspecified	00	Unspecified	0	Unspecified		
1	Common	01	3" partition	1	To be rendered		

2	High structural strength	02	$4\frac{1}{2}$″ stretcher	2	Bagged
3	Facing—single	03	9″ stretcher	3	Pointed
4	,, —double	04	9″ English		etc.
5	Patterned, 1 face	05	9″ Flemish		
6	Patterned, 2 face	06	9″ English garden		
7	Parallel	07	9″ Flemish garden		
8	Fire	08	11″ cavity		
9	Others	09	$13\frac{1}{2}$″		
		10	$1\frac{1}{2}$ brick with cavity etc.		

H-47 **Location (L)**=Project Zone/Storey

H-48 **Specification**

Utility tags	Significance of (field)
XB	Building project
XC	Total cost
XD	Drawing number
XE	Building element
XO	Operative occupations
XQ	Quantity surveying code reference
XR	Components, commodities required
XS	Stage of programme when fixed
XT	Labour times
YL	Length (m)
YN	National specification clause number
YS	Area (m^2)
YT	Tools required for job
YV	Volume (m^3)
ZF	Completion time
ZJ	Preceding work-piece
ZK	Subsequent work-piece
ZS	Starting time
BK	Type of bricks
DH	Wall height
DT	Wall thickness
LO	Location e.g. wall and room
MT	Type of mortar
*	Description

H-49 **Essential graphic geometry**

This example illustrates how a classification system, more complex than that fo door, may be bent into the code format. In the example the intention has been t provide a framework of classification of the common geometrical features incorporate in architectural drawings with a view to providing a useful compression of data whe storing the information in coded form. Considerable software would have to b developed to enable computers to build up drawings from this type of classificatio and data, but defining a set of categories in this way should serve as a useful specifi cation to which the software specialists could work. The data suggested is designe so as to be easily obtained from drawings and to be of a fairly standardised form.

Definition of position requires the setting up of co-ordinate systems. In the examples that follow a right-handed set of orthogonal co-ordinates 2, y, z are assumed with z vertically upwards. This leads to the positive x axis being 90 degrees clockwise of the y axis and suggests that the y axis is more suitable as the reference axis of drawings and forms.

H-50 **Primary classifier (P)** 7 EGG1 **Essential Graphic Geometry**

H-51 **Sub-classification (C)**

N_1	N_2		N_3		Data requirements
0 add	0	general	0	U	
			1	Set of points	
4 subtract			2	Set of points defining curve	x,y,z co-ordinates
			2	Set of points defining surface	of points
7 obliterate			4	Set of points defining solid	
	1	point	0		x,y,z of point
	2	st. line	0		x,y,z of end points
	3	triangle	0	rt. angle, sides / / x & y axes (hor.)	x,y,z of end point
			1	rt. angle, sides / / x & z axes (vert.)	of hypotenuse
			2	rt. angle, sides / / y & z axes (vert.)	
			3	general xyz space	x,y,z of 3 vertices
	4	rectangle	0	sides / / x & y axes (hor.)	x,y,z of end points
			1	sides / / x & z axes (vert.)	of a diagonal
			2	sides / / y & z axes (vert.)	
			3	general in xy (hor.) plane	
			4	general in xyz space	
	5	rectangular par.-pip.	0	edges / / x, y & z axes	x,y,z of end points
			3	general with sides in xy plane	of internal diagonal
			4	general in xyz space	
	6	circle	0	in an xy plane (hor.)	x,y,z of centre
			1	in an xz plane (vert.)	and radius
			2	in an yz plane (vert.)	
			3	general	x,y,z of centre & 2 non-diametric points
	6	arc	4	in xy plane	x,y,z of end points & radius (end points express clockwise on arc)
			5	in xz plane	
			6	in yz plane	
			7	general	
	7	cylinder	0	axis / / z (vert.)	data as for circle & of the end nearest
			1	axis / / y (hor.)	

		2	axis / / x (hor.)	the origin & length
		3	general	
	7	4	sphere	x,y,z of centre & radius

Sub-classification (C) continued

N_4		Extra data	N_5N_6	(Spare)
0	point diagrammatic representation		U	
1	line diagrammatic representation			
2	surface diagrammatic representation			
3	solid diagrammatic representation			
4	surface formed by sweep of 2 D figure along vector	xyz of vector of sweep		
5	enclosed surface formed by sweep of 2 D figure along bector			
6	enclosed surface formed by sweep of 3 D figure along vector			
7	solid formed by sweep of 2 or 3 D figure			

H-52 **Location (L)**=Drawing No.

H-53 **Specification**

Utility tags	Significance of (field)
XB	Building project (C)+(L)
XD	Drawing number
XX	Co-ordinates
YY	
ZZ	
AT	Angles of rotation
AU	
AV	
DD	Drawing datum (w.r.t. PD)
FD	Form datum (w.r.t. DD)
FM	Special form identity number
FN	Similar form special identity number
OR	Direction of reference axis (z axis?)
PD	Project datum
PT	Point (x, y, z)
RA	Radius (metres)
SF	Scaling factor
VX	Vector along x axis
VY	Vector along y axis
VZ	Vector along z axis
*	Description

Examples of the code in use

Commodity file

H-54 The nature of a central commodity file for the construction industry will depend on factors such as:

type and frequency of use

response time required for retrievals

total size of file, rate of increase and backlog that can be tolerated

performance and size of the computer system, particularly the storage devices used to handle the file

state of development of the software to deal with the file

relationships of the organisation(s) maintaining the file with manufacturers of commodities, the computer installations and the construction industry as a whole

H-55 In giving the example which follows, these assumptions have been made:

Sophisticated software for converting input documents to on-file documents is not available or necessary: therefore the input code corresponds quite closely to the on-file code.

Manufacturers will perform some of the encoding since the use of code will shorten the documents produced and the key to the code will provide guidance as to what information is relevant. However, an organisation closely associated with the central computer will have responsibility for finally checking the data and for preparation of computer input. The commodity file will be held on a large storage device similar to a fixed magnetic disc which is capable of giving direct access to any part in a relatively short time.

An identification system will be developed which requires two fields, one identifying the merchant manufacturer of the commodity, the GIRO number being suitable for this, and the other being allocated by the merchant manufacturer or authoritative body—this number sometimes will be associated with the utility tag XA. An index arranged according to these two fields and giving the commodity record addresses will enable rapid access to the main file using these identification numbers. Each record contains information relevant to one commodity which has a unique identification number. A product, similar but not identical to another, may have a short record which refers to the record of the other.

The records on the file have a record heading with fixed format and position. The rest of the record is partly fixed in format and position and partly free in format and position.

All the records associated with one primary classifier (P) will be grouped together and ordered according to the sub-classification (C). Ordering of the primary classifiers might be alphabetic or according to some broad commodity grouping such as that used in the record heading. The latter method might be particularly useful for manual filing systems or computer files with serial access, whereas for the large direct access computer files the ordering of these blocks of information associated with the primary classifier should not be of importance.

H-56 The general form of the file might be:

Contents of file	Notes
Record order Number etc.	Information of significance to the commodity file such as record number, record length, type of record date of input, etc.
(P) (C) (L) (XA) (ZA)	Recording heading: (P)=classifier (without redundant 3), (C)=sub-classifier, (L)=Giro No., (XA)=non-significant identity No., (ZA)=commodity group.
Descriptive Name	Brief verbal description of commodity
Property indicators	Bit pattern with bits set according to whether properties are present or not
	Specification: free position of fields, free format (?)
*text	Plain description—any length
	Links to other records in the file
Record order number	Next record
etc	

H-57 **Example of codes for doors used in a commodity file**

The illustration here concerns a manufacturer's range of five similar doors and the records that might be held on a central computer commodity file.

A plain description of coded information given for the first door and continued in the first record of this example might be as follows (symbol / / corresponds with the manufacturer's information given below and is inserted for reference):

Manufacturer is identified by GIRO number 1234567 / / Commodity identity number
← XA 1234 —
is 1234 / /. Manufacturer's own code for the product is POP1 / /. The product is
→ ←
(see paras 31 and 33 for the interpretation of the sub-classification and property
indicators), 1¼ in. x 1 ft 9 in. x 6 ft /, hinged /, flush frame door / with fire rating of
— sub-classification (C)=021210 —
less than ½ hour / / which is suitable to be used with a restoring action /
→ ← property indicators — h —
left / or right hung / /. The product is in commercial commodity group B2 i.e. doors
–l— r → ← ZA B2 —

(any materials) and gear / /. Cost is £3 each (see para 32 for utility tags) / /.
——————→ ←——————— XC 3·0 ———————→
Weight 20 kg / /. Payment is required within 1 month of delivery / /. Availability
←— YW 20→ ←——————— etc. ———————
within 21 days of firm order / /. Construction details include $\frac{1}{4}$ in. beech lipping / /

frame of 3 in. x 2 in. softwood / / panel core of honeycomb paper / /. Panels are

of plywood / / conforming with standard specification N 736 / /. Minimum economic

batch is 150 doors / /. Sound insulation of 25 dB / /.

The other four doors of the range are basically similar to the first with change in description resulting from the different dimensions. It is assumed that the manufacturer has allocated identity numbers 1234, 1235 and 1236 to the first three doors and that the last two of the range comply with the national standard specifications laid down for standard commodities N 123 and N 125. A drawing (not presented here) is supplied with the first door only; the essential geometric information of this drawing might be stored within the record but more probably will be on a separate file, possibly a microfilm file in the office of the enquirer.

H-58 Information supplied by the manufacturer for the five doors might be as follows:

GIRO=1234567 / / XA=1234 / / DOR1, plywood faced hinged internal door, XM POP1 / / (C)=011210 / / hlr / / Commodity group B2 / / XC 3·0 / / YW 20 / / ZP del+1 mth. / / AV 21 / / ME $\frac{1}{4}$in. beech / / MF softwood 3 x 1 / / MI honeycomb paper / / MP plywood / / MQ N736 / / NB 150 / / SI 25.

* Special textured finish to facilitate painting. Viewing or ventilation panels can be provided on larger sizes. Special sizes made to order. Orders over 150 have free carriage up to 100 miles from London.

XA=1235 ditto 1234 except (C)=021210, XC 3·2, YW 21·8, XM POP 2.
XA=1236 ditto 1234 except (C)=031210, XC 3·3, YW 24·0, XM POP 3.
XA=N123 ditto 1234 except (C)=071210, bfg, XC 3·4, YW 27·0
AV 14, XM POP 4.
XA=N125 ditto N123 except (C)=091210, XC 4·0, YW 30·0 XM POP 5.

H-59 This information would then be checked by the central organisation and modified to make it acceptable to the input software used for making additions to the computer commodity file. After input to the computer, the data might result in commodity records on the computer file as follows:

Contents of file

012345	etc			
DOR1	011210	1234567	01234	B2
Door hinged, internal plywood faced				
00000001000100000100000000				
XC 3·0	XD 12345/1		XM POP 1	
YW 20	ZP del+1 mth.		AV 21	

Notes

Record number 12345, etc

Commodity record heading

Brief description

Property indicators hl and r

DH 1829	DT 32	DW 533
ME ¼" beech	MF softwood 3 x 1	
MI honeycomb paper	MP plywood	
MQ N736	NB 150	SI 25
* Special textured finish to facil-		
itate painting. Viewing or ventila-		
tion panels can be provided on larger sizes		
Special sizes made to order		
Orders over 150 have free carriage		
up to 100 miles from London		
012456+	012566+	012748+

Specification including repetition of dimensions in metric units

Plain description

Records referring to this record

012456	etc			
DOR 1	021210	1234567	01235	B2
XC 3·2	XM POP 2	YM 21·8	DH 1981	
012345 –				

Record No. 12456, etc

Heading

Brief specification

Record referred to

012566	etc			
DOR 1	031210	1234567	01236	B2
XC 3·3	XM POP 3	YM 24·0	DH 1981	
DW 610				
012345–				

Record No. 12566, etc

Heading

Brief specification

Record referred to

012748	etc			
DOR 1	071210	1234567	N123	B2
01000111000100000100000000				
XC 3·4	XM POP 5	YW 27·0		
AV 14	DH 1981	DT 38	DW 762	
012345–	013234+			

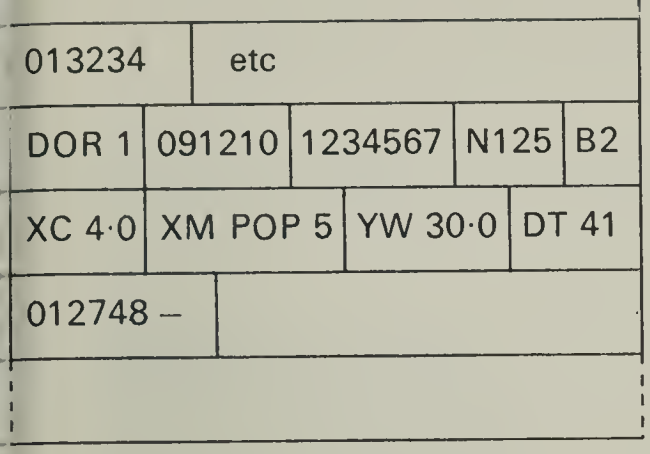
Record No. 12748 etc

Heading

Property indicators bfghlr present

Brief specification

Record referred to and also referring to this record



H-60 A file such as this should be capable of a variety of uses provided software is available to carry out the necessary searches. A commodity information service could be provided which would rapidly answer questions of the kind:

Who manufactures products similar to product A?

What products are available with characteristics C?

Give particular details of product A.

Figure H-1 illustrates a possible method of dealing with the second type of question with the type of commodity file proposed. (The use of English in the various responses does in fact presuppose the existence of advanced software and also a comprehensive preferred vocabulary).

Structure of a project file

H-61 The records of a project file may be similar to the commodity file in that they may have similar record headings which can be followed by coded and uncoded information. However, the records would differ in the following respects:

1 They would not be confined to those associated with commodities but could be associated with any of the primary classifier types, particularly building and site, building elements, functional spaces and systems, resources, and work-pieces.

2 Locational information in the record headings would be relevant to the project and not the commodity source.

3 They would contain many links internal to the file, e.g. between building type and elements, elements and resources, etc. and also many links with non-project files e.g. links to the commodity file by means of the commodity identity number, links to files of drawings, etc.

The general form of a possible project file, which would be useful for co-ordinating the project as well as many of the more mechanical tasks, is given in figure H-2, though little detail can be given until much more of the code has been developed.

Figure–H1 A possible method of dealing with a commodity enquiry

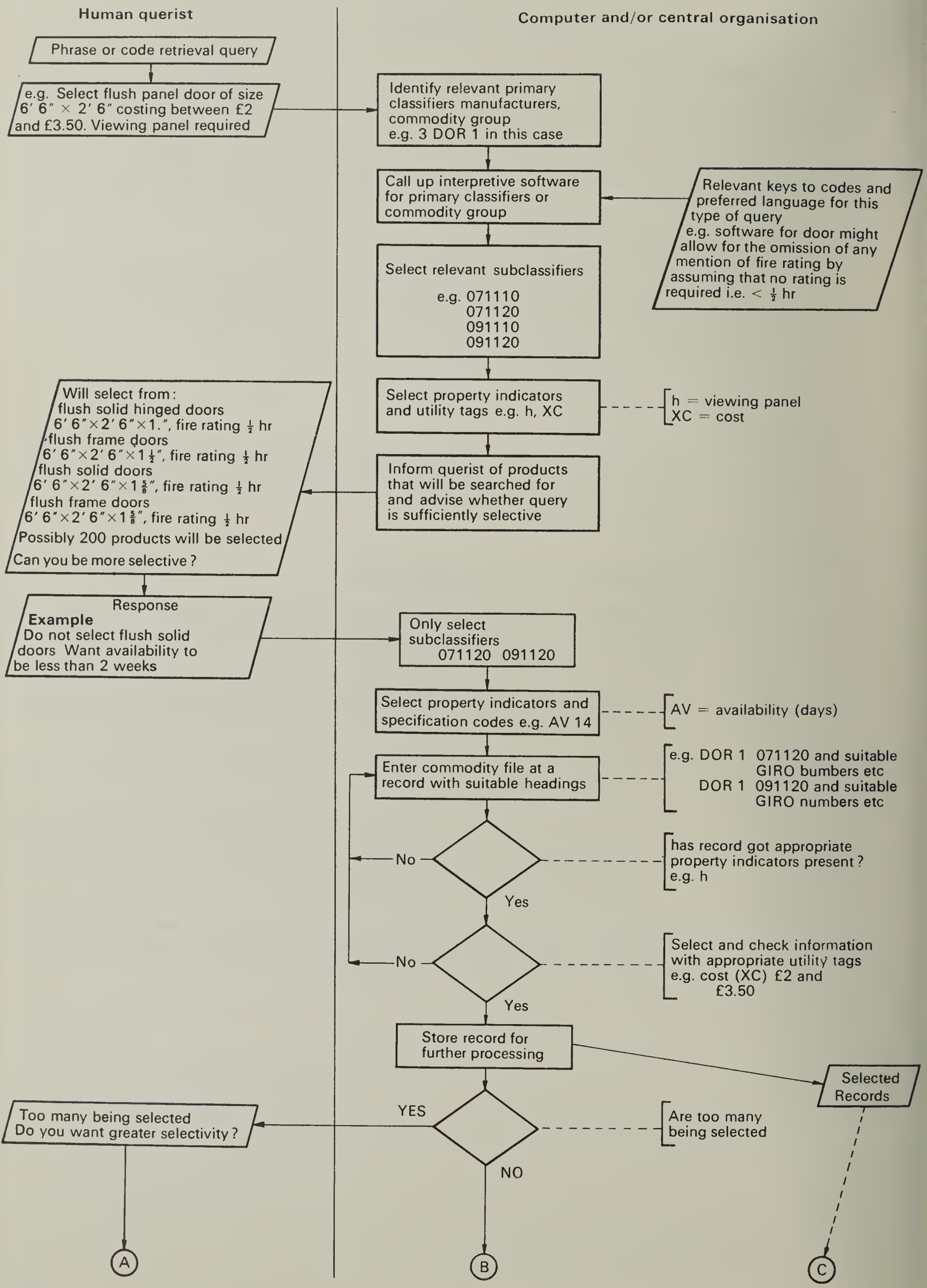
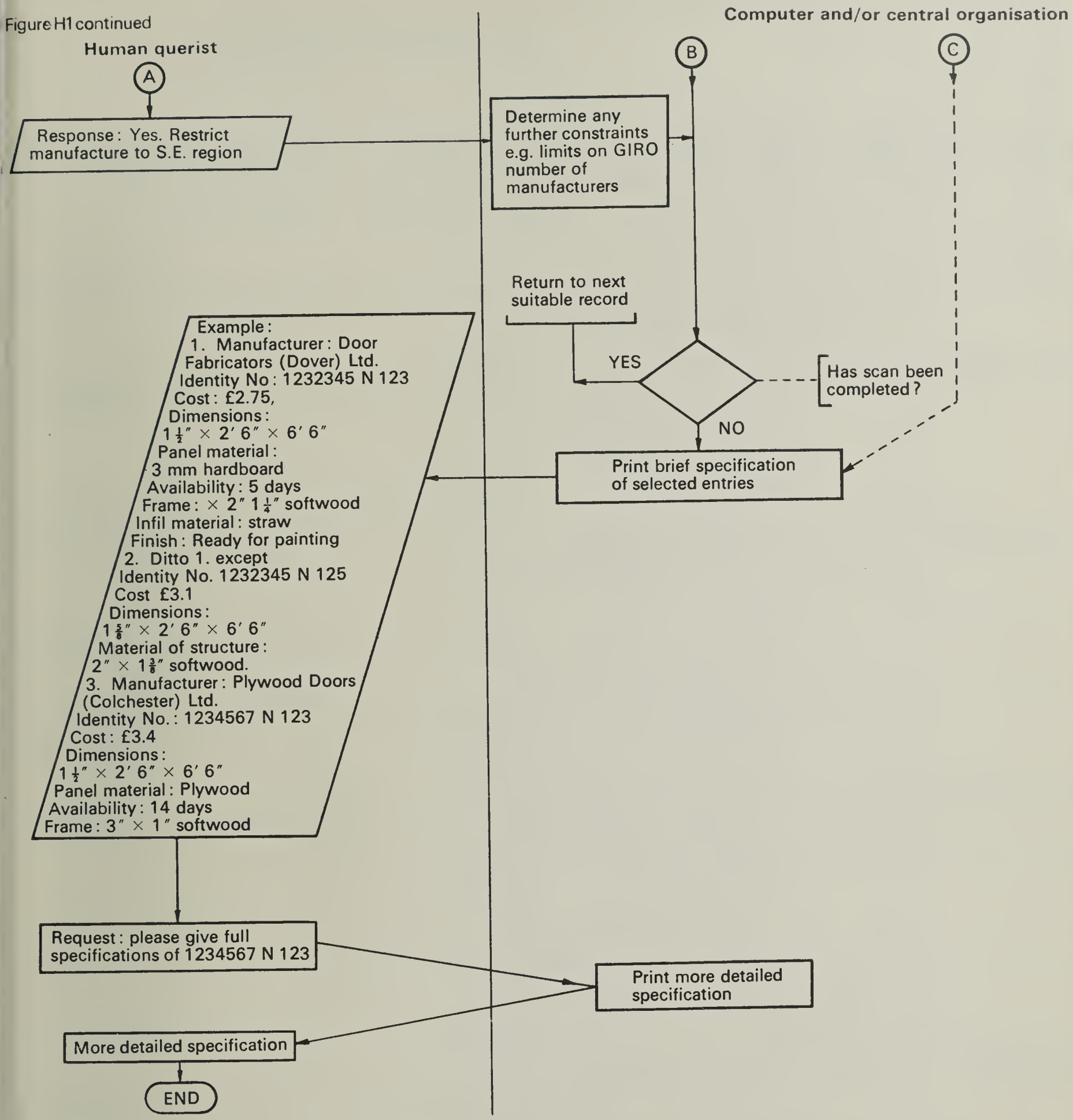

Human querist
Computer and/or central organisation
Phrase or code retrieval query
e.g. Select flush panel door of size 6′ 6″ × 2′ 6″ costing between £2 and £3.50. Viewing panel required
Identify relevant primary classifiers manufacturers, commodity group e.g. 3 DOR 1 in this case
Call up interpretive software for primary classifiers or commodity group
Relevant keys to codes and preferred language for this type of query e.g. software for door might allow for the omission of any mention of fire rating by assuming that no rating is required i.e. < ½ hr
Select relevant subclassifiers
e.g. 071110
071120
091110
091120
Select property indicators and utility tags e.g. h, XC
h = viewing panel
XC = cost
Will select from:
flush solid hinged doors 6′ 6″×2′ 6″×1.″, fire rating ½ hr
flush frame doors 6′ 6″×2′ 6″×1 ½″, fire rating ½ hr
flush solid doors 6′ 6″×2′ 6″×1 ⅝″, fire rating ½ hr
flush frame doors 6′ 6″×2′ 6″×1 ⅝″, fire rating ½ hr
Possibly 200 products will be selected
Can you be more selective ?
Inform querist of products that will be searched for and advise whether query is sufficiently selective
Response
Example
Do not select flush solid doors Want availability to be less than 2 weeks
Only select subclassifiers
071120 091120
Select property indicators and specification codes e.g. AV 14
AV = availability (days)
Enter commodity file at a record with suitable headings
e.g. DOR 1 071120 and suitable GIRO bumbers etc
DOR 1 091120 and suitable GIRO numbers etc
No
has record got appropriate property indicators present ? e.g. h
Yes
No
Select and check information with appropriate utility tags e.g. cost (XC) £2 and £3.50
Yes
Store record for further processing
Selected Records
YES
Too many being selected Do you want greater selectivity ?
Are too many being selected
NO
A
B
C

Figure H1 continued



Figure–H2 Extracts from a project file with some primary links (not lines of information flow)

Key to codes used in this figure

Primary classifiers

1	BTE	1	Building type		
1	FSE	1	Functional space		
2	BSE	1	Building structure		
2	FNN	1	Foundation		
3	CLN	1	Column		
3	CBE	1	Column base		
4	BRK	1	Brickwork		
4	CMX	1	Concrete mix		

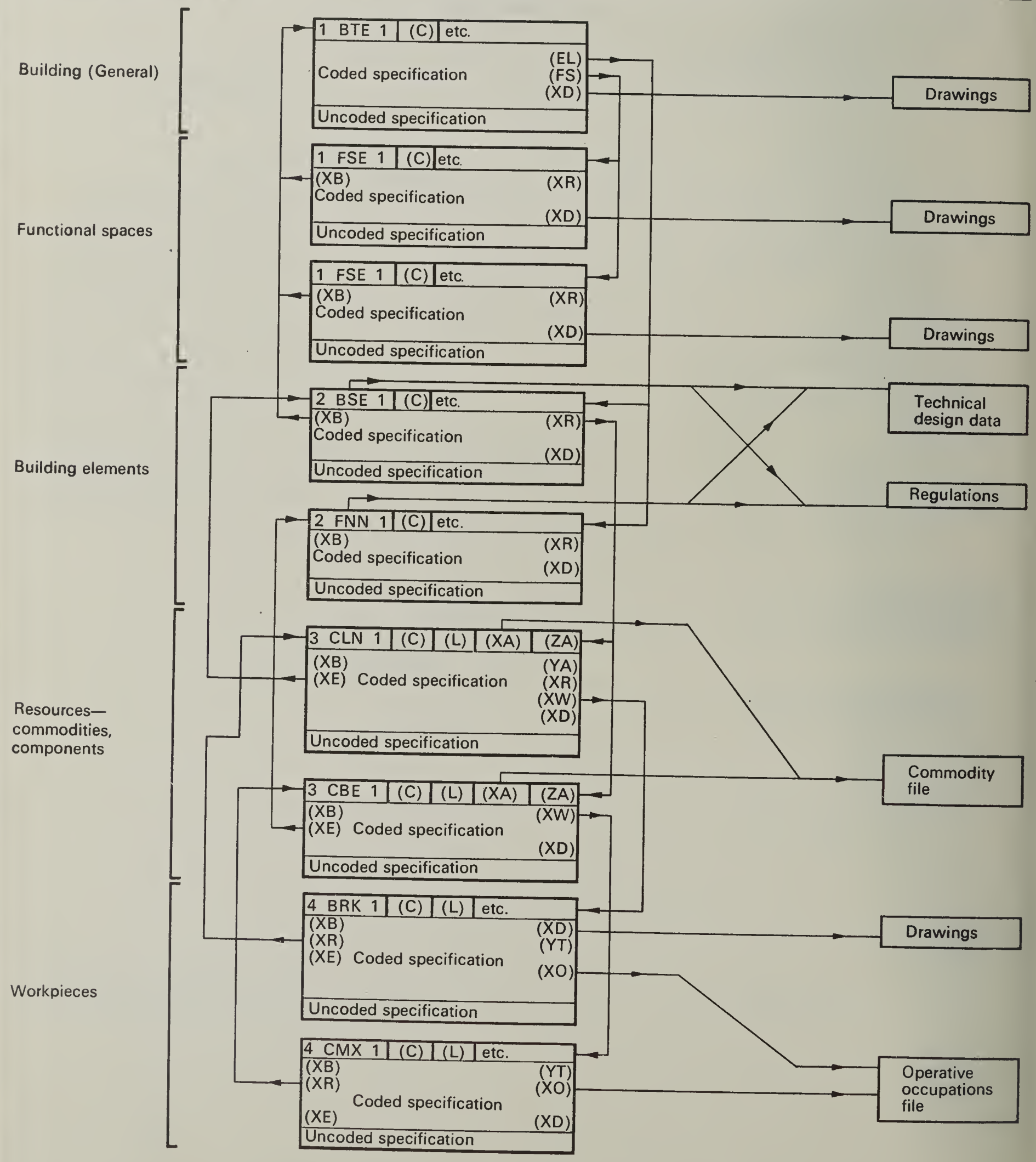
Utility tags

EL	Elements incorporated
FS	Functional spaces
XB	Building project
XE	Element within project
XA	Identification number
XO	Operatives involved

Sub-classification = (C)

Location = (L)

ZA	Commodity Class
XR	Components incorporated, required
XW	Workpieces associated
YA	Components attached
XD	Drawing numbers
YT	Tools required



Glossary

Activity
An application of resources to operations. The extent of an activity may be equal to or less than an operation, but will not exceed an operation. An activity is essentially a planning (production) concept.

Cash flow
Schedule of times or dates at which payments for resources of all kinds are received and made, and the amounts.

Net cash flow is the algebraic sum of inputs and outputs and is used to calculate project profitability, e.g. by internal rate of return or other discounting methods.

Category
Any convenient grouping of descriptors.

Central processor
Part of a computer accessible to all participants in a project.

Code
A set of symbols grouped or ungrouped which may be used to facilitate the storage, transmission or manipulation of information and data.

Encoding
The process of generating a coded form from the original form of information or data.

Decoding
The process of transforming the coded form into information in plain language.

Code key
A set of rules and equivalencies to enable encoding and decoding to be performed.

Fields (of codes)
Groups of symbols of a code, each group having significance.

Brisch codes
The Brisch technique is a system of classification and coding generally tailor-made for an individual requirement, developed by E. G. Brisch and Partners Ltd. It is based on four fundamental principles:

1 The essential requirements of each particular user must be satisfied.
2 Only permanent characteristics must be selected and used in designing the classification.
3 There must be one place and one place only for each item.
4 Adequate space must be allowed for future expansion.

Commodity
The general term covering products, materials and components—an article of trade.

Component
Manufactured article in a form for which certain dimensions are specified, e.g. a door, window, steel joist.

Product
Any substance which has been processed but has to be worked into shape when it arrives on site, e.g. rolls of felt, wallpaper.

Material
Any substance which arrives on site in an unprocessed state. It may, like timber have been cut up for trading and transport, but is formless as far as building is concerned.

Construction method
Broad method of tackling the way in which a building will be constructed, e.g. in situ concrete frame placed by a tower crane using truck-mixed concrete

Descriptor
Word relevant to a subject or subjects included in a set of documents, including subject headings, the specification of the document (title, publisher etc.) and its address on a sheet in a file, or on a magnetic tape, or the like.

Design realization — All that lies between design and construction. Commences when the design has resulted in the choice of principal structural techniques and materials and is completed at the commencement of planning of construction work on site and resource allocation.

Design — Those functions that use scientific principles, technical information and imagination to define a project capable of performing pre-specified functions with economy and efficiency.

Construction — The planning of work, including financial budgeting and control and the allocation, acquisition and deployment on site of resources to achieve the completion of a project.

Document — One of the forms in which information is conveyed. Specifically, in Chapter 6, a collection of related items of coded information.

Element — An element is that part of a building which always performs the same function irrespective of building type.

Facet — One of the whole group of divisions, produced when a subject is divided according to a single characteristic.

File — A collection of records with a common interest. They may be traditional files, or recorded on microfilm or recorded on magnetic tapes.

Commodity file — A store of information about commodities.

Project file — A cumulative store of information about any particular project.

Flow diagram — A means of graphically displaying the essence of a system including feedback, etc., in a simplified line diagram.

Form — The geometrical shape and the main dimensions of the proposed building.

Format — The position of symbols in a code i.e. the layout of the code.

Fixed field format — A type of code in which each field has a particular fixed length and the ordering of letters and numerals or other symbols within the field is invariant.

Function — A division of the building process usually marking the completion of an identifiable goal. Functions are discharged by the execution of procedures.

Function space — A space or a system of spaces within a building which are intended primarily for one identifiable purpose.

Functional system — Those parts of a project which together contribute to one particular aspect of its functioning. e.g. the structural load-carrying system, the fire protection system, the weather-excluding system. Some parts may serve more than one functional system.

Genesys — A suite of programs capable of dealing with commonly occurring structural engineering problems.

Identification — A labelling of information or commodities so that they can be referred to without recourse to a complete description.

Information schedule — List of the information which is used in carrying out a procedure.

Operation — Any part of the work, either permanent or temporary, involved in construction that can be undertaken by a man or by a gang without interruption by the work of other men or other gangs.

Procedure — Procedures consist of one or more actions applied to a set of data. In these information is received, processed and put out.

Determinate procedure — Procedures involving no judgement in which conclusions are reached without recourse to subjective decision.

Non-determinate procedure — Draw on experience and knowledge to assess the non-measurable characteristics.

Program	A set of instructions and any other necessary data for controlling a computer run.
Programme	An expression of a plan for construction of one or more projects related to time and to the resources required. It includes such a plan covering a number of similar projects rather than their separate organisation.
Project data	The data that develops with a project and is specific to it, starting with a statement of the clients requirements and concluding with the appraisal of the way in which these requirements have been met.
Resources	The labour, commodities, sub-contractors, managers, services and capital at the disposal of the contractor for the purpose of constructing the project.
Routine	The formalised description in flow chart form of a procedure.
Standard detail	A drawing and specification of the construction of a small part of a building which is accepted as appropriate for particular circumstances and can be used repeatedly without alteration.
Task	A number of activities, an activity, or part of an activity, given to a man or a gang as a single job. NB. An activity is typically a sub-operation allocated to a location or group of locations, and a task will be a sub-activity, i.e. an operation carried out at a particular location.
Technical solutions	The particular solution used to achieve the performance required of a functional system or of a building element.
Terminal	Human or telecommunication/computer interface.
Vehicle	The medium by which information is communicated. e.g. letter, schedule, drawing, specification, magnetic tape.
Work-piece	A sub-division of a building that is convenient to a contractor for placing purposes or in instructing operatives. Additionally, some work-pieces will be related to jobs such as scaffolding or demolition that do not form parts of a finished building.

Printed in England for Her Majesty's Stationery Office by McCorquodale & Co. Ltd., London
HM3122 Dd 142241 K20 2/69 McC3309

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Published by
HER MAJESTY'S STATIONERY OFFICE
To be purchased from
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13a Castle Street, Edinburgh 2
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SBN 11.670197.8.

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